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EFFECT OF INBREEDING ON THE ESTIMATED BREEDING SOUNDNESS OF YEARLING HEREFORD BULLS

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IT is realized that bulls differ widely in their effectiveness in settling cows and that variation in fertility has an important bearing on the success of the cattle enterprise. In the Colorado Agricultural Experiment Station herd the use of electro-ejaculation techniques opened the way for eliminating from the herd potentially infertile bulls by making possible an examination of physical and semen characteristics prior to the breeding season.

This study was designed to determine the extent and significance of the effect of inbreeding on the estimated breeding soundness of yearling bulls by a comparison of the physical and semen characteristics of inbred, linecross and cooperators' outcross bulls. The terms fertility and infertility in this paper were based upon estimated breeding soundness and not upon actual reproduction rate.

King (1916), in an experiment with albino rats, found no adverse effect on fertility after inbreeding as closely as possible for 22 generations and selecting only the best breeders in each generation. Other results, however, generally indicate that inbreeding causes a deterioration in fertility. Wright (1922, 1923) found lessened fertility due to inbreeding in guinea pigs and in the Duchess strain of Shorthorns. McPhee *et al.* (1931) failed in an attempt to establish an inbred strain of Poland China due to infertility; and Winters *et al.* (1943) in developing the Minnesota No. 1, found an indication of deterioration in fertility due to inbreeding. In reference to males alone, inbreeding appears to raise the frequency of specific structural and spermatic defects. Abnormalities observed by various workers are as follows: hypoplasia of the testes, Eriksson (1943); arrested development of the Muellerian ducts, Fincher and Williams (1926); abnormal sperm and low concentrations, Gregory *et al.* (1951); and "knobbed" formation of the acrosome, Donald and Hancock (1953).

Methods and Materials

The data on evaluation of breeding soundness presented in this paper were obtained from observations on 215 unselected bulls located at the San Juan Branch of the Colorado Agricultural Experiment Station and 96 outcross bulls belonging to cooperating breeders. The evaluations were

[1] The authors wish to acknowledge the assistance of Drs. F. Scott and E. J. Carroll, Veterinarians, and Kent Riddle, Assistant Animal Husbandman.

[2] Approved for publication as scientific paper SS-590 of Colorado Agricultural Experiment Station. It is included in the Western Section Project W-1 in cooperation with the A.P.H. Branch, U.S.D.A.

made in the years 1955–1958, inclusive. The cooperators' bulls were brought to the Station in conjunction with the annual performance testing of bulls and, following the test, were evaluated for estimated breeding suitability along with the station bulls. All the bulls were approximately of the same age and were fed under similar conditions for approximately 5 months prior to the examination for breeding suitability.

The Experiment Station bulls, which included 93 inbred and 122 linecross bulls, were produced from 15 inbred lines and rotational crosses of these lines. The herd bulls sired concurrently the inbred and linecross progeny. A few of the linecross bulls were the result of incrossing, the crossing of inbred lines within a breed, but the majority were topincrosses,

TABLE 1. NUMBER OF INBRED AND LINECROSS BULLS BY LINE

Line of sire	No. linecrosses	No. inbreds	Range of inbreeding coefficients	Average inbreeding coefficients
Bonanza	17	5	0.19–.39	0.32
Brae Arden	12	16	.32–.54	.40
Colorado	13	9	.29–.56	.42
Don	9	10	.24–.42	.32
Fort Lewis	1	..	...	...
La Plata	1	3	.25–.35	.29
Mesa	6	2	.20–.21	.20
Monarch	13	9	.25–.39	.33
Prospector	13	14	.12–.34	.23
Real Prince	..	1	...	.33
Rover	7	..	...	...
Royal	7	9	.32–.54	.39
San Juan	18	12	.14–.42	.27
Tarrington	..	1	...	.25
Verde	5	2	.35–.47	.41

or the progeny of inbred sires bred to unrelated outbred females of the same breed; these outbred females were sired by inbred bulls from other lines.

Several of the inbred lines were started in 1946. One line originated from a group of six heifers purchased in a herd closed to outside breeding since 1926 (Stonaker, 1951). Six other lines were established in 1946 around sires in use at Ft. Lewis A & M College. Other groups of heifers were purchased from various herds through the philanthropy of the Sears Foundation. In most cases sires were bred to their daughters, thus initiating a rapid increase in inbreeding. The level of inbreeding attained at this time is in excess of most of those usually reported in cattle. A pedigree description of the various lines is available in Colorado Agricultural Experiment Station General Series paper 683. The number of inbred and linecross bulls in each line and the inbreeding coefficients of the inbred bulls are shown in table 1. The inbreeding coefficients of both

calf and dam within lines were computed by means of Wright's formula, as presented by Lush (1949). The information presented in this table is based only upon those bulls included in this study; it does not include some lines being developed in leased herds.

The evaluations used in classifying each bull as a satisfactory, questionable or unsatisfactory prospective breeder were made by a Colorado State University veterinarian prior to each breeding season and included both a physical examination and a semen evaluation. Semen collections were obtained by electro-ejaculation (three commercially manufactured instruments have been used) and the criteria used in scoring the semen sample were based on degree of vigor, concentration, morphology and percent sperm alive. Degree of vigor was evaluated in the raw sample by viewing a drop on a warm slide at 100X magnification; concentration was estimated by observing the gross sample in the collection tube; percent of live cells was determined by the supra-vital eosin-nigrosin staining technique described by Blom (1950), and morphology studies were classified according to the description of Blom with minor variations. In addition to semen evaluation, physical unsuitability could cause a bull to be classified as unsatisfactory.

To make possible a statistical analysis, numerical grades of 4-3-2-1, respectively, were assigned to the descriptive terms of very good, good, fair and poor given those semen characteristics of morphology, concentration, and degree of vigor. For percent alive the original numerical values were used. Physically the bulls were classified as satisfactory, questionable or unsatisfactory with no scoring system.

The data were first analyzed by use of means for each mating system, and this was followed by Chi-square and analysis of variance tests to determine the nature and significance of the differences noted. Analysis of variance was used where a range in value existed, as for the individual semen characteristics, and Chi-square was used where individuals were enumerated into three distinct classifications.

Results and Discussion

The data presented in table 2 suggest the existence of quantitative differences between inbreds, linecrosses and cooperators' outcross bulls. An interesting observation on overall breeding soundness of the bulls can be noted from the comparison of percentage of bulls classified satisfactory, questionable or unsatisfactory within each mating system. Among mating systems, the most striking difference is the percentage of those classified as unsatisfactory, 22.6% of the inbred bulls; but, only 11.5% of the cooperators' outcrosses and 9.8% of the linecrosses were classified as unsatisfactory prospective breeders. When the numbers within each mating system were analyzed by the Chi-square test of independence, the value of 7.48 indicated a statistically significant difference ($P<.05$) in estimated breeding soundness between the bulls in the inbred and line-

cross groups, but an X^2 of 4.23 indicated no significant difference between Fort Lewis inbreds and cooperators' outcrosses.

A comparison of overall breeding soundness within mating systems has been presented. In addition the data have been segregated into information on physical suitability and semen characteristics. The results are recorded in tables 2 and 3.

Physical suitability, which is based on any defect which might obviously interfere with a bull's ability to produce semen or serve cows, does not appear to differ significantly, numerically or in percentage, with mating system (table 2). Non-significant Chi-square values of 1.64 between inbreds and linecrosses and 0.93 between inbreds and cooperators' bulls were found. Based on percentages, the cooperators' bulls appeared the more satisfactory physically. While there is little difference between the percentage of linecross and inbred bulls which were classified in the combined questionable and unsatisfactory groups, there were more unsatisfactories and fewer questionables among the inbred bulls. This suggests a more serious rather than more frequent occurrence of physical abnormalities or deficiencies among the inbreds.

As shown by the means of the individual semen characteristics in table 2, generally there was a lowering of grade with the classification from satisfactory through questionable down to unsatisfactory. To determine the nature and significance of differences in grades of the individual semen characteristic for each source of variation, an analysis of variance was conducted (table 3). A highly significant difference was found between years for percent sperm alive, and this appeared to be due primarily to 1955; but, it is not known whether there was a chance difference in that year as compared to others, or, as suggested by the original data, a real difference in the levels of grading by different veterinarians. There was a significant difference between mating systems within years for concentration, but this was certainly due to greater but unexplainable variation in 1958. Morphology seemed the most variable of the individual semen characteristics, and it appears that the adverse effect of inbreeding is particularly pronounced in this semen characteristic. Highly significant differences were found for years and mating systems within years; however, there probably would not have been as large a difference for mating systems within years had it not been for less variability in 1956. A significant difference between mating systems was found only for morphology. While the other semen characteristics individually did not show significant differences between mating systems, it seems the combined effects of all the semen characteristics plus physical suitability acted additively to bring out a significant difference between mating systems in predicted overall suitability for breeding.

It seems certain at this point that there is a difference in fertility levels between the inbreds and crosses. That inbreeding seems adversely to effect sperm morphology more than other semen characteristics leads to a

TABLE 2. CHARACTERISTICS AFFECTING THE EVALUATION OF BREEDING SOUNDNESS OF YEARLING BULLS

Mating system	No.	Percent of total	Age in months	Inbreeding	Grade, degree of vigor	Grade, concentration	Grade, morphology	Percent alive	Physical evaluation	
									No.	Percent
			Means							
Inbreds										
Satisfactory	59	63.4	13.0	.32	3.7[a]	2.7	3.5	69	79	84.9
Questionable	13	14.0	12.8	.37	3.2	2.3	2.2	63	3	3.2
Unsatisfactory	21	22.6	12.8[a]	.35	2.6[a]	1.5	1.7	40[a]	11	11.8
All inbreds	93	100	12.9[a]	.33	3.5[a]	2.4	2.9	63[a]	93	....
Linecrosses										
Satisfactory	96	78.7	13.1	...	3.8	2.5	3.7	67	105	86.1
Questionable	14	11.5	12.8[a]	...	3.2	1.9	1.8	65[a]	7	5.7
Unsatisfactory	12	9.8	12.9	...	3.2	2.2	2.5[a]	62[a]	10	8.2
All linecrosses	122	100	13.0[a]	...	3.6	2.4	3.3[a]	66[a]	122	...
Cooperators' outcrosses										
Satisfactory	70	72.9	13.3	...	3.7	2.8	3.5	70	86	89.5
Questionable	15	15.6	12.6[a]	...	3.7	2.5	2.2	62	2	2.0
Unsatisfactory	11	11.5	13.2	...	2.2[a]	1.9	1.9[a]	69[a]	8	8.3
All outcrosses	96	100	13.0[a]	...	3.6[a]	2.6	3.1[a]	69[a]	96	...

[a] Occasionally an observation on a particular characteristic is missing; however, all means in this table are relative to the actual number of observations involved, irrespective of the n value indicated.

TABLE 3. ANALYSIS OF VARIANCE OF SCORES OF INDIVIDUAL SEMEN CHARACTERISTICS

Source	Degree of vigor		Concentration		Morphology		Percent alive	
	df	ms	df	ms	df	ms	df	ms
Years	3	0.86	3	3.32	3	13.70**	3	4148.82**
Mating system within years	8	0.46	8	1.67*	8	2.43**	8	359.23
Mating system	2	0.74	2	2.34	2	6.28*	2	537.36
Years x mating system	6	0.36	6	1.45	6	1.15	6	299.85
Within year and mating systems	292	0.44	300	0.72	297	0.91	290	275.07

* $P<.05$.
** $P<.01$.

consideration of effects on spermatogenesis. The difference in morphology should not be due to any difference in inherent level of average genetic competence of the sperm cells from inbred or linecross sources. This would seem apparent since the haploid sperm cells from a population of inbred lines should have the same frequencies of genes as the haploid cells from a population of line crosses derived from those inbreds. From this it appears that the reason for inferior morphology scores for sperm from inbreds must be associated with an inferior somatic environment for the developing sperm rather than with the genotypes of the sperm *per se*.

Inbreds averaged only a few days younger than the linecrosses and cooperators' bulls, so age does not help to explain differences in their estimated breeding soundness. Furthermore it seems unlikely that age

TABLE 4. DISTRIBUTION OF BULLS WHEN GROUPED BY INTENSITY OF INBREEDING

Coefficient of inbreeding	No. satisfactory	No. questionable	No. unsatisfactory	Percent questionable or unsatisfactory
Inbreds				
0.0–.09	0	0	0	....
.10–.19	5	0	1	16.7
.20–.29	18	4	7	37.9
.30–.39	25	6	8	35.9
.40–.49	11	0	3	21.4
.50–.59	0	3	2	100.0
Linecrosses	96	14	12	21.3
Outbreds	70	15	11	37.1

has influenced a bull's classification as to satisfactory, questionable or unsatisfactory, for the mean age of bulls classified satisfactory was only very slightly higher than that of bulls classified unsatisfactory (table 2).

There is some suggestion of a retarding effect of inbreeding upon age of sexual maturity, for it is not uncommon for inbred bulls of the mean age to be classified questionable or unsatisfactory because of physical or seminal immaturity or both. Unfortunately only a few bulls classified either questionable or unsatisfactory have been reevaluated or observed for breeding performance in a herd; so it is not possible to offer definite evidence on an effect of inbreeding on sexual maturity.

If inbreds fail to mature as rapidly as linecrosses or if innately lower fertility exists among inbreds, it would seem reasonable to suppose that as inbreeding increased fertility would decrease. The average inbreeding coefficient of all inbreds in this study was 0.33 with a range of 0.12–0.56 and standard deviation of 0.09, but intensity of inbreeding does not appear to differ appreciably within those inbred bulls classified satisfactory, questionable or unsatisfactory (tables 2 and 4). Thus variations in level of

TABLE 5. ESTIMATED BREEDING SOUNDNESS OF INBREDS AND LINECROSSES BY LINE OF SIRE

Line of sire	Inbreds			Linecrosses		
	No. satis.	No. ques.	No. unsatis.	No. satis.	No. ques.	No. unsatis.
Bonanza	3	0	2	13	2	2
Brae Arden	13	1	2	9	1	2
Colorado	2	1	6	12	0	1
Don	5	2	3	7	2	0
Fort Lewis	..	..	..	1	0	0
La Plata	2	0	1	1	0	0
Mesa	2	0	0	4	2	0
Monarch	6	3	0	10	1	2
Prospector	10	1	3	10	2	1
Real Prince	1	0	0	..	..	..
Rover	..	..	..	5	1	1
Royal	5	2	2	7	0	0
San Juan	9	2	1	12	3	1
Tarrington	0	0	1	..	..	..
Verde	1	0	1	5	0	0

inbreeding within the limits of these data, do not show a close association with levels of infertility. It must be acknowledged, however, that numbers are small and sampling errors surely must be great.

A further explanation for the apparent deterioration of fertility among inbred bulls is suggested by a comparison of the lines (table 5). Infertility appears more pronounced in certain lines, e.g., Colorado and Don, and it seems possible that inbreeding may be affecting fertility within a few lines rather than causing a generally linear deterioration among all the inbreds. With the small and disproportionate numbers within the lines at this time, a statistical comparison of the lines did not produce meaningful results and therefore was not presented in this paper.

Summary

A study on 311 yearling Hereford bulls showed that inbreds were inferior to linecrosses in estimated breeding soundness. A comparison of the bulls' overall classification as satisfactory, questionable or unsatisfactory prospective breeders showed a statistically significant difference between inbred and linecross bulls, but a non-significant difference between inbred and cooperators' outbred bulls.

Differences in physical suitability for breeding of inbred, linecross and outbred bulls were not statistically significant. An analysis of the sources of variation for individual semen characteristics indicated highly significant differences from year to year for morphology and percent sperm alive and a significant difference between mating systems for sperm

morphology. Inbreeding intensity within the limits of these data did not appear definitely to account for increased infertility among the inbreds. There was however, some suggestion of a retarding effect of inbreeding on sexual maturity. The data further suggested that lower fertility may be due to characteristic infertility in a few lines rather than among all inbreds.

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INFLUENCE OF PROGESTERONE TREATMENT ON POST-PARTUM REPRODUCTIVE ACTIVITY IN BEEF CATTLE[1]

W. D. Foote, E. R. Hauser and L. E. Casida

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THE intervals from parturition until involution of the uterus, and to first ovulation and first heat show considerable variation in cattle. All of these intervals are affected by such a factor as nursing (Clapp, 1937; Wiltbank and Cook, 1958). Buch *et al.* (1955) showed an association between the interval to first heat and that to uterine involution. The lengths of these intervals depend on post-partum changes involving endocrine adjustments.

Progesterone has been used to inhibit ovulation and estrus in cattle (Christian and Casida, 1948; Ulberg *et al.*, 1951). It is possible that uterine involution rate might also be affected by such a hormone treatment.

The present study was an attempt to decrease the variation in the times of first ovulation and first heat in a group of post-partum beef cows by suppressing ovarian activity with a standard dose of progesterone. This dose was presumed to inhibit ovarian activity for a uniform interval after injection. A test also was made for an effect of this treatment on the interval to uterine involution and on fertility at the first estrus subsequent to treatment.

Material and Methods

Data were collected from January 1956 to May 1958 on a total of 62 cows, 44 Angus and 18 Shorthorn. Twenty-four of these cows were 2 to 3 years old, 28 of them 4 to 8 years old and 11 of them 10 years or older. Before calving all animals were paired within breed and parity (primiparous and pluriparous) on the basis of relationship and month of calving. One cow of each pair was selected at random and injected with 1 mg. progesterone per lb. body weight subcutaneously in a starch emulsion on the 14th day after calving. The other member of each pair remained untreated. All treated and untreated cows of both breeds remained in the same herd thus being subjected to essentially the same environment. The herd was rotated on grass and mixed pasture during the months of May through October of each year and were maintained in dry lot, receiving mixed hay and grass or corn silage the remainder of the time. Both the treated and untreated cows nursed their calves throughout the experiment.

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The times of uterine involution and first ovulation were determined by weekly rectal palpations of the reproductive organs beginning 15 to 22 days after parturition. Complete involution was judged by (a) a return of the uterus to a normal location in the pelvic or near pelvic region, (b) normal and approximately equal size of the uterine horns with little further reduction in their size, and (c) attainment of the normal uterine tone and consistency. A cow was considered in heat if she stood to be mounted by another cow or by an estrogen implanted ovariectomized heifer which ran with the herd. The cows were observed for heat twice daily.

TABLE 1. INTERVALS FROM CALVING TO UTERINE INVOLUTION, FIRST OVULATION, AND FIRST HEAT IN PROGESTERONE TREATED AND UNTREATED COWS

			Treated [b]			Untreated		
Breed	Interval from calving to	No. pairs [a]	Range (days)	Average	Mean square [c]	Range (days)	Average	Mean square [c]
Angus	Uterine involution	22	31–62	41.4	62	29–56	40.9	50
Shorthorn	Uterine involution	9	30–59	42.6	66	30–54	42.6	55
Both breeds	Uterine involution	31	30–62	41.7	64	29–56	41.4	53
Angus	First ovulation	21	33–101	60.7[d]	377	14–64	35.9[d,f]	191
Shorthorn	First ovulation	9	38–88	62.1	309	27–75	55.2[f]	233
Both breeds	First ovulation	30	33–101	61.1[d]	358	14–75	41.7[d]	203
Angus	First heat	21	33–154	86.0	979	29–150	66.9	996
Shorthorn	First heat	9	45–97	76.0	246	27–108	62.7	488
Both breeds	First heat	30	33–154	83.0[e]	769	27–150	65.6[e]	851

[a] Each pair includes 1 treated and 1 untreated cow—pairing was on the basis of parity, relationship, and time of calving.

[b] Treatment consisted of a single injection of 1 mg. progesterone per lb. body weight on the 14th day after calving.

[c] Mean squares of both breeds combined were calculated within breeds.

[d] Intervals to first ovulation differed significantly at the 0.01 level between treated and untreated cows within the Angus breed and for both breeds combined.

[e] Intervals to first heat differed significantly at the 0.05 level between treated and untreated cows when the breeds were combined.

[f] Intervals to first heat differed significantly at the 0.01 level between the untreated Angus and Shorthorn cows.

Results and Discussion

Average lengths and variances of the post-partum intervals studied are shown in table 1. Neither length nor variation of interval to uterine involution was affected by progesterone treatment. The average interval in days was 41.7 and 41.4 for the treated and untreated groups, respectively. If the ovaries do affect involution rate they would appear to do so through some agent other than progesterone. No report was found in the literature on the effect of ovariectomy on the post-partum involution rate of the bovine uterus.

The average interval to first ovulation was 61.1 days for the treated group and 41.7 days for the untreated group. The difference of 19.4 days was significant ($P<0.01$). The difference between the intervals of the

treated and untreated groups was more pronounced in the Angus than in the Shorthorn breed. There was a statistically significant difference between the untreated Angus and Shorthorn cows which probably accounts for the breed variation in the treatment difference observed.

Treatment did not decrease the variation in ovulation time; in fact, the within breed mean square was slightly, although insignificantly, greater for the treated than for the untreated group. The average intervals to first heat were 83.0 days and 65.6 days for the treated and untreated groups, respectively. This difference was significant ($P<0.05$). Variation in time to first heat did not differ significantly between the treated and untreated groups. The tendency for cows to ovulate one or more times before showing heat was evident in both the treated (40%) and untreated (50%) groups although some cows first ovulated at first estrus. The average interval from first ovulation to first heat was 21.9 days for all treated cows and 23.9 days for all untreated cows. The corpora lutea formed from "pre-heat" ovulations appeared to be normal in size and shape.

Progesterone treatment did not appear to have an effect on conception rate. Twenty-seven treated and 25 untreated cows were bred naturally at first post-partum heat. Two Angus bulls and one Shorthorn bull were used. Both treated and untreated Angus cows were bred to each Angus bull. Twenty treated (74.1%) and 20 untreated (80.0%) conceived. Willett (1950) reported the breeding efficiency at first service of dairy heifers treated with progesterone during the estrual cycle to be similar to that of untreated heifers. Trimberger and Hansel (1955) and Ulberg (1955), working with dairy and beef cows, respectively, have suggested a temporary decrease in fertility following treatment with high dosages of progesterone. It is possible that in the present study latent effects of the injected progesterone had all been eliminated before the animal was bred so that the reproductive system was under endogenous hormone control.

Summary

The effect of a single post-partum injection of progesterone (1 mg. per lb. body weight, subcutaneously, 14 days after calving) on the intervals from calving to involution of the uterus, first ovulation, and first heat were studied in 62 cows (44 Angus and 18 Shorthorn). Treatment had no effect on the interval from calving to involution of the uterus, 41.7 days for treated as compared to 41.4 days for the controls. The average post-partum interval to first ovulation was significantly longer in the treated than in the untreated group (61.1 vs. 41.7 days). The average intervals from calving to first heat for the treated and untreated groups were 83.0 and 65.6 days, respectively. The difference was significant.

Although progesterone treatment tended to delay ovarian activity and consequently the expression of heat after calving, it did not decrease the

variability of any of the intervals studied. Treatment had no significant effect on conception rate. For 27 treated and 25 untreated cows bred at first heat the average conception rates were 74.1% and 80.0%, respectively.

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EFFECTS OF ORALLY ADMINISTERED GOITROGENS UPON THYROID ACTIVITY AND METABOLIC RATE IN RUMINANTS [1]

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SEVERAL feeding trials with livestock and poultry (Sykes *et al.*, 1953) have been conducted with various goitrogenic compounds in attempts to increase fattening through altered thyroid activity. The results of these trials have been varied and generally unsuccessful due to undesirable side effects of most of these compounds and insufficient understanding of the altered physiology produced by different levels of goitrogens. Thiouracil, the goitrogen which has been tested most extensively and found to alter thyroid activity to some extent (Pipes *et al.*, 1956) has generally been found to be unsatisfactory as a fattening agent for ruminants (Barrick *et al.*, 1949; Beeson *et al.*, 1947; Burroughs *et al.*, 1957). Andrews *et al.* (1947) found thiouracil did not have a significant effect on growth rate in lambs. The purpose of the present study was to determine the degree of alteration in thyroid activity in cattle and sheep when different levels of two goitrogens were orally administered.

Experimental

The goitrogens investigated were thiouracil and methimazole. Barrick *et al.* (1950) demonstrated that thiouracil generally did not have a marked goitrogenic effect upon lambs. Methimazole (1-methyl 2-mercaptoimadazole) was given most attention since this goitrogen has been reported to be 40 times as potent as thiouracil in the rat (Kabake *et al.*, 1954) and has recently shown considerable promise as a fattening agent in cattle (Burroughs *et al.*, 1958). Four techniques were employed in this investigation in measuring altered thyroid activity in lambs and cattle. The first technique made use of Iodine^{131} as a tracer of thyroid activity; the second measured thyroid weights in cattle and lambs fed different amounts of the two goitrogens for varying lengths of time; the third made use of basal metabolism measurements of goitrogen-treated lambs; and, the fourth consisted of growth hormone and thyrotropic hormone assays of the anterior pituitary glands of goitrogen-fed cattle.

Iodine^{131} Methods. Two groups of cattle and one group of lambs were used in the Iodine^{131} experiments. The first group of cattle consisted of

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eight yearling Hereford steers, each weighing initially about 750 lb. They were individually fed in an open shed a fattening type ration and orally administered per animal, daily, different amounts of thiouracil by six-week periods as follows: Period 1 (steers 1 through 8–none); Period 2 (steers 1a and 1b–none, steers 2a and 2b–1 gm., steers 3a and 3b–3 gm., steers 4a and 4b–5 gm.); Period 3 (steers 1a and 1b–none, steers 2a and 2b–5 gm., steers 3a and 3b–7 gm., and steers 4a and 4b–9 gm.); Period 4 (steers 1a and 1b–none, steers 2a and 2b–11 gm., steers 3a and 3b–14 gm., and steers 4a and 4b–20 gm.). The second group of cattle consisted of four Hereford steer calves weighing initially about 375 lb. each. These calves were confined in steel metabolism cages in an insulated room maintained at 70° F. They were individually fed daily 10 lb. of a fattening type ration for four three-week periods during which time methimazole was orally administered (per animal daily) in the ration as follows: Period 1 (calf 1 through 4–none); Periods 2, 3 and 4 (calf 1–none, calf 2–300 mg., calf 3–600 mg., calf 4–1200 mg.).

The group of lambs consisted of 12 western shorn animals averaging initially about 65 lb. They were confined to steel metabolism cages in an insulated room maintained at 70° F. throughout four periods of three weeks each. The lambs were individually fed a fattening type ration containing methimazole (per lamb per day) as follows: Period 1 lambs 1a and 1b through 6a and 6b–none); Periods 2 through 6 (lambs 1a and 1b–none, lambs 2a and 2b–4 mg., lambs 3a and 3b–16 mg., lambs 4a and 4b–32 mg., lambs 5a and 5b–64 mg., and lambs 6a and 6b–128 mg.).

The $Iodine^{131}$ was quantitatively injected intravenously in one dose in the first group of cattle, a needle and syringe being used with a bi-valve apparatus for rinsing during the experiment. With the second group of cattle and with the lambs the $Iodine^{131}$ was injected similarly except that a polyethelene heparinized catheter was inserted into the jugular vein, use being made of a "California" bleeding needle. The amount of $Iodine^{131}$ injected at one time in an animal was 120 microcuries in 20 ml. of solution in the first cattle experiment. Sixty microcuries in a similar volume of solution was injected per animal in the second cattle experiment, and 15 microcuries injected per animal in the lamb experiment.

After injection of the radioactive iodine, counts were taken at intervals of 1–3 days during each experimental period in an area directly exterior to a thyroid lobe with a bismuth coated geiger tube coupled to a decimal scaler. The area directly exterior to the thyroid lobe was located with a portable survey rate meter at a point in the neck region displaying maximum activity. All counts were corrected for dead time, decay and background count taken on the rump of the animal.

From the counting data collected after maximum apparent uptake, a regression coefficient was calculated in terms of decrease in log of corrected activity per day. These regression coefficients were transformed

by the following formula to percent decrease in iodine content per day for purposes of ease of study

$$\text{Percent decrease/day} = 100 - \text{antilog } (2-b)$$

in which b=corrected regression coefficient. Also calculated from the counting data was maximum theoretical uptake of $Iodine^{131}$ by the thyroid gland.

Thyroid Weights. The estimation of thyroid activity by thyroid weight was determined on five groups of animals at the time of slaughter. The thyroid glands were removed from the carcasses at the packing plant, dissected free of extraneous fatty tissue and weighed. The 12 lambs fed methimazole and injected with $Iodine^{131}$ described earlier constituted one group. The eight yearling steers fed thiouracil and injected with $Iodine^{131}$ constituted the second group of animals from which thyroids were removed and weighed. The other three groups of animals were: (1) Six lots (five animals each) of two-year-old Hereford steers slaughtered after 79 days of oral administration of methimazole at levels of 0, 200, 400, 600 and 800 mg. per animal per day, respectively; (2) four lots (18 animals each) of yearling Hereford steers slaughtered after 134 days of oral administration of 0, 300, 0–600,[3] and 600 mg. of methimazole per animal per day, respectively; (3) six lots (six animals each) of yearling Hereford steers slaughtered after 176 days of oral administration of 0, 300 and 600 mg. of methimazole per animal per day, respectively, with and without oral administration of stilbestrol.

Metabolism Studies. Twelve lambs were fed a fattening type ration in which lambs 1a and 1b received no methimazole, 2a and 2b received 4 mg., 3a and 3b received 16 mg., 4a and 4b received 32 mg., 5a and 5b received 64 mg., and 6a and 6b received 128 mg. of methimazole per animal per day. Metabolic rate was determined by measuring expired carbon dioxide of lambs fasted for 48 hours and in a standing position for 60 minutes during the determination. Three determinations were made on each lamb. The apparatus used in these studies is illustrated in figure 1 and shown in operation in figure 2. The weight of the carbon dioxide measured in grams was multiplied by a factor of 3.325 in estimating calories of body heat production at an estimated respiratory quotient of 0.72 (Brody, 1945; Dukes, 1955).

Anterior Pituitary Assays. The anterior pituitary glands were collected from one group of 30 cattle at the time the thyroids were removed during slaughter at the packing plant. These cattle, as earlier described in six groups of five animals each, had been fed for 79 days a fattening ration in which methimazole was orally administered at levels of 0, 200, 400, 600 and 800 mg. per animal per day, respectively. The anterior pituitary glands were trimmed, weighed, dried and prepared for assay according to the procedure of Greenspan *et al.* (1949).

[3] Fed 600 mg. methimazole for last 78 days of feeding period.

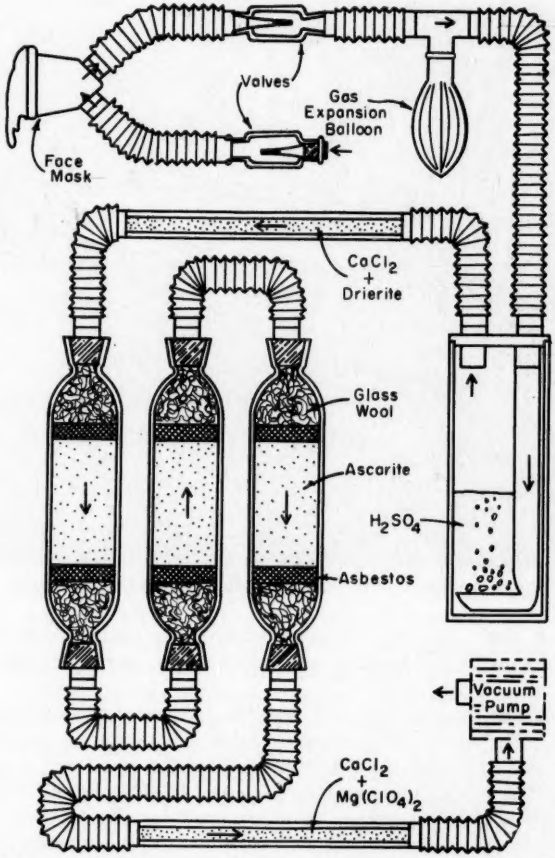

Figure 1. Diagram of carbon dioxide respiration apparatus for lambs.

Results

Iodine^{131} *Studies.* The Iodine^{131} studies with the first group of steers orally treated with thiouracil yielded results suggesting little or no alteration in thyroid activity when up to 20 gm. of thiouracil was fed in the diet. The net daily decrease in Iodine^{131} content of the thyroid gland averaged about 3% in cattle receiving no thiouracil. No significant difference from this mean value was found in any of the cattle receiving from 1 to 20 gm. of thiouracil daily, despite the fact that the high levels severely decreased the cattle's appetite as measured by feed consumption.

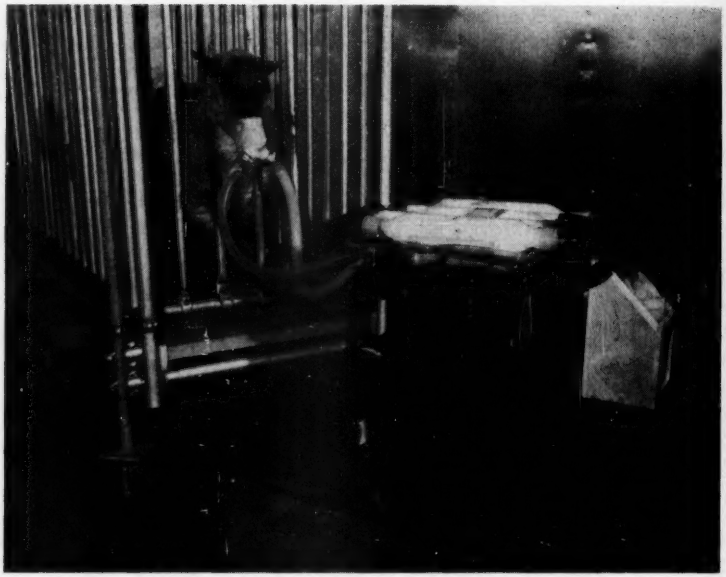

Figure 2. Carbon dioxide respiration apparatus in operation.

That these levels of thiouracil when mixed in the cattle ration had little or no effect on thyroid activity was substantiated in the data on thyroid weights.

Methimazole, on the contrary, exhibited considerable influence upon thyroid Iodine^{131} in cattle as shown in table 1. The average net daily percent decrease in thyroid Iodine^{131} was 6.2 for the zero level as compared with 9.5, 10.5 and 30.7 for the 300-, 600- and 1200-mg. levels of methimazole, respectively. The average value obtained for the 1200-mg. level as compared to the control or the two lower levels was greater ($P=0.01$) as shown by analysis of variance. The relative theoretical uptake of iodine in the cattle thyroid glands was erratic; and, although instances of de-

TABLE 1. NET DAILY PERCENT DECREASE IN THYROID IODINE^{131} CONTENT OF STEERS RECEIVING DIFFERENT LEVELS OF METHIMAZOLE

Level methimazole fed daily per steer, mg.	Net daily percent decrease, thyroid Iodine^{131}	Change, net daily percent decrease from control
None	6.2	0.0
300	9.5	3.3
600	10.5	4.3
1200	30.7	24.5

TABLE 2. WEIGHT OF THYROID GLANDS FROM LAMBS FED DIFFERENT LEVELS OF METHIMAZOLE AND STILBESTROL

	Methimazole (mg./lamb/day)			
Stilbestrol	0	5	35	65
mg./lamb/day	gm.	gm.	gm.	gm.
0	3.2	3.8	5.6	5.0
2	2.9	3.2	5.9	14.1
Average	3.0	3.5	5.8	9.5

creased uptake occurred, due to methimazole treatment, this was not a consistently observed effect.

The levels of methimazole used in the lamb experiment (0, 4, 16, 32, 64 and 128 mg. per animal daily) produced average net daily percent decreases in thyroid Iodine^{131} of 5.2, 8.9, 5.8, 6.2, 11.7 and 7.7, respectively. Although all average values for the treated lambs were higher than the average control value, the magnitude of the differences were relatively small and the statistical significance was of a low order. Also the maximum theoretical uptake data of Iodine^{131} in the lamb thyroid glands were little affected by the levels of methimazole administered.

Thyroid Weights. The results with both lambs and cattle, on the average, showed a consistent influence (thyroid enlargement) from methimazole treatment. This thyroid enlargement was accentuated by oral stilbestrol as shown in table 2, but to a much lesser extent in lambs than in cattle. The increases in thyroid size in cattle are shown in table 3. It is apparent that both the daily amount of methimazole and the length of time of its administration influenced size of thyroid in the cattle.

Metabolism Results. The metabolic rate of lambs (table 4) showed no effect from the levels of methimazole administered. These rates were somewhat higher than basal metabolic rates because the lambs were in a standing position and not entirely in a post-absorptive condition. Methimazole had no significant influence upon rectal temperature of the lambs during the course of the metabolism measurements.

TABLE 3. WEIGHT OF THYROID GLANDS FROM CATTLE FED DIFFERENT LEVELS OF METHIMAZOLE

Methimazole	79-day exp.	134-day exp.	176-day exp.
mg./steer/day	gm.	gm.	gm.
0	30	33	30
200	52	..	..
300	..	80	91
400	65	..	..
0–600	..	90	..
600	70	168	188
800	105	..	..

TABLE 4. METABOLIC RATE AND RECTAL TEMPERATURE OF LAMBS RECEIVING DIFFERENT LEVELS OF METHIMAZOLE

Methimazole	Metabolic rate	Metabolic rate	Rectal temp., ° F.
mg./lamb/day	Cal/day	Cal/kg./day	
0	1241	32	101.9
4	2088	54	102.9
16	1556	37	102.0
32	1789	42	102.1
64	1503	37	102.1
128	1536	37	102.6

Growth Hormone and Thyrotropin Assays. The results of the assays upon the anterior pituitary glands of the cattle fed in the 79-day experiment are presented in table 5. In general, both the wet and dry weights of the gland increased with methimazole administration. Also, the amounts of growth hormone and thyrotropic hormone per gm. of dry gland increased with methimazole feeding. Expressed as the amounts of these hormones present in this gland per steer, the largest relative difference was shown between the control and the methimazole-treated cattle.

Discussion

It is evident from these studies that thiouracil when fed in a cattle ration at levels up to about 2 gm. per 100 lb. of body weight was ineffective in altering thyroid activity as measured by three criteria, namely, (1) uptake of radioactive iodine, (2) net daily decrease in $Iodine^{131}$ and (3) weight of the thyroid gland. These results appear to be contrary to a report by Pipes *et al.* (1956) who concluded that about one-half this amount of thiouracil will completely block the thyroid gland of all species of ruminants. This difference in results may be apparent rather than real since the Missouri workers administered thiouracil as single daily doses in gelatin capsules, whereas in the present studies the thiouracil was incorporated in the feed and administered throughout each 24-hours depending

TABLE 5. GROWTH HORMONE AND THYROTROPIN CONTENT OF THE ANTERIOR PITUITARY GLAND OF METHIMAZOLE TREATED CATTLE

Methimazole administered	Weight of gland		Growth hormone		Thyrotropic hormone	
	Wet	Dry				
mg./steer/day	gm.	gm.	Mcg./ gm.D.M.	Mcg./ steer	I.U./ gm.D.M.	I.U./ steer
0	0.93	.24	5500	1300	290	70
200	0.91	.23	....	....	...	...
400	1.08	.27	8000	2100	890	235
600	1.06	.27	5600	1500	530	145
800	1.13	.28	7300	2100	400	112

upon the eating habits of the cattle. It seems plausible that the effectiveness of a given level of thiouracil may be decreased by this latter method of oral administration.

The usage of higher levels than those tested for thiouracil mixed in cattle rations for purposes of altering thyroid activity does not appear promising because of the unpalatable nature of the compound. In fact, most cattle feeding trials with thiouracil (Burroughs *et al.*, 1957; Beeson *et al.*, 1947) have resulted in decreased food consumption. The present experimental evidence suggests that this decreased food consumption in earlier experiments was due to something other than altered thyroid activity; most likely, it was due to the unpalatable nature of thiouracil.

One of the first observations made in this study with methimazole was its acceptability, as compared to thiouracil, when incorporated into cattle rations at levels shown to be effective in altering thyroid function. Levels of methimazole ranging from 200 to 1200 mg. per animal per day were effective in altering thyroid activity as measured by radioactive iodine measurements and actual weights of the thyroid glands in cattle.

With respect to lambs, the effectiveness of methimazole appears promising in altering thyroid activity. However, the $Iodine^{131}$ studies and also the thyroid weight measurements suggest that higher levels of methimazole per unit body weight are needed in lambs as compared to cattle to bring this about. As much as three times a given cattle dosage per unit body weight may be necessary to bring about a comparable influence in lambs. Also, the levels of methimazole tested in the metabolism rate studies failed to demonstrate a measurable influence in lambs.

The influence of methimazole in altering thyroid action in cattle and in turn altering the amount of thyrotropin and growth hormone in the anterior pituitary gland offers evidence bearing upon the physiological mechanism whereby methimazole stimulates rate of growth and/or stimulates fattening in beef cattle. The partial blocking of the thyroid gland would be expected to increase thyrotropin secretion by the anterior pituitary gland. Since larger amounts of growth hormone were also present in the anterior pituitary gland of cattle fed methimazole, it appears that this accounts for the growth stimulation during the first several weeks the goitrogen is administered. This situation is somewhat analogous to the stimulation of growth hormone in the pituitary gland when stilbestrol is administered to cattle (Struempler *et al.*, 1957). It would appear, however, that prolonged administration of methimazole to cattle eventually results in sufficient blocking of the thyroid gland that additional growth fails to take place, and cattle subsequently fatten more readily as has been shown in feeding trials (Burroughs *et al.*, 1959).

Summary

Studies were conducted with cattle and sheep to determine the effect of the goitrogenic compounds, thiouracil and 1-methyl 2-mercapto imadazole

(methimazole), on thyroid activity and metabolic rate. Thyroid activity was evaluated on the basis of weight of the thyroid gland and also by two techniques involving radioactive iodine. Metabolic rate was determined on lambs with a carbon dioxide absorption apparatus. Prolonged oral administration to eight steers of thiouracil at levels ranging from 1 to 20 gm. per day had no effect on thyroid activity or carcass quality; feedlot performance was depressed only by the high level. Thiouracil was unpalatable at the higher levels. Methimazole altered to varying degrees thyroid activity in lambs receiving from 4 to 128 mg. per day; it had no observed effect on metabolic rate. Methimazole at levels from 200 to 1200 mg. per day in steers consistently and progressively altered thyroid activity on the basis of both iodine elimination rate from the thyroid and thyroid weight. It increased the weight of the pituitary glands of steers as well as the amount of growth hormone and thyrotropic hormone contained in the gland.

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EFFECT OF RESTRICTED FEEDING, CROSSBREEDING AND SEASON OF BIRTH ON AGE AT PUBERTY IN SWINE [1]

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GILTS which reach puberty at earlier ages will experience more heat periods before breeding age than later maturing gilts and may be expected to farrow larger first litters because of higher ovulation rates (Warnick *et al.*, 1951; Robertson *et al.*, 1951a, 1951b; Self *et al.*, 1955). Restricted feeding has been shown to alter age at puberty in swine. The effect obtained, however, has been variable in the different experiments. Robertson *et al.* (1951b) and Burger (1952) found that puberty was delayed by limited feeding, while Self *et al.* (1955) reported that limited feeding reduced age at puberty as compared to full feeding. The restriction of energy intake, only, has been reported by Haines *et al.* (1959) to retard age at puberty, while Gossett and Sorensen (1959) found that limited-energy gilts attained puberty at a slightly but nonsignificantly earlier age than full-fed gilts. Foote *et al.* (1956) reported that reciprocal crossbred gilts attained puberty significantly earlier than the average of their parent breeds. Season of birth also has been indicated as a source of variation in age at puberty in swine. Wiggins *et al.* (1950) and Gossett and Sorensen (1959) reported a tendency for fall-born gilts to attain puberty at an earlier age than spring-born gilts.

The present investigation was conducted to obtain more information on the effects of restricted feeding, crossbreeding and season of birth on age at puberty. The influence of growth rate on age at puberty was also studied.

Experimental Procedure

Chester White (CW) and Poland China (PC) gilts from the University of Wisconsin purebred herd were used in each trial of this study. Chester White-Poland China crossbred gilts were used also in trial IV. Trials I, III, V and VI were conducted with spring-born gilts, and trials II and IV with fall-born gilts. The gilts of each breed were allocated at random to full and restricted feeding levels at the beginning of each trial—as gilts attained 70 days of age in trial I, 75 or 115 days in trial II, 90 days in trials III and V and at an average age of 105 days in trial VI. The 75-

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and 115-day gilts in trial II were treated similarly but were kept in separate pens. Gilts in trial IV were put on experiment as they reached 90 days of age but were allowed a restricted feeding level only.

The gilts were weighed when put on experiment and at two-week intervals thereafter until they completed the experiment. All gilts in this study were kept in dry-lot and had access to housing and outside concrete slabs at all times.

Daily heat checks with vasectomized boars were begun when the oldest gilt in a trial reached 150 days of age and were continued until all gilts had attained puberty or had reached 300 days of age (320 days in trial VI) without exhibiting their first estrus. Gilts of the latter type were slaughtered and if no abnormalities were observed, they were considered to have attained puberty at the age of slaughter, for purposes of statistical analysis.

In all of the trials, full feeding involved self feeding a low fiber growing ration, and except in trial I where the intake of the whole ration was restricted, restricted feeding was designed to allow gilts approximately the same quantities of nutrients other than energy as full-fed gilts received.

Limited-fed gilts in trial I were hand-fed the same ration received by full-fed gilts (self-fed), but at a level of about two-thirds of the concurrent intake of the full-fed gilts. The initial protein level of the ration (19%) was reduced to 13.7% when the gilts averaged 154 days of age. Restricted feeding in all other trials was accomplished by self feeding a high fiber ration—the low fiber ration modified by substituting corn cobs for corn and adjusting the main protein sources upward to compensate for the diluting effect of the cobs.

Full-fed gilts in trial II received a 3.9% fiber ration. Restricted-fed gilts were started on a 15.8% fiber ration, but because those gilts started at 75 days of age failed to gain at an adequate rate (two-thirds of 75-day full-fed gilts) early in the experiment, the percentage fiber in the ration was reduced to 11.4% for one month; it was then returned to the 15.8% level. It was intended for the protein levels of the low and high fiber rations to be approximately equal, but this was prevented by an unnoticed error in feed ordering (the amounts of oats and soybean oil meal desired in the ration being switched); the resulting levels being 12.4 to 14.3% as compared to 17% in the low-fiber ration.

In the remainder of the trials where full feeding was practiced (trials III, V and VI), full-fed gilts were self-fed a 5.9% fiber ration. Limited-energy gilts in trials III and IV were started on a 13.3% fiber ration fed *ad libitum*. After one month, in trial III, the percentage of fiber was increased to 14.2%; when the gilts averaged 154 days of age the fiber content was increased to 18% and the protein level was reduced from 15.8 to 14.2%. The protein level of the low fiber ration was similarly reduced at 154 days of age from 16 to 14%. The same rations and feeding plan outlined for trial III were used in trials V and VI except that the limited-

energy gilts were started on the ration containing 14.2% fiber. The rations used in this study are the same as those reported previously by Waldorf *et al.* (1958).

Although the intake of all nutrients was limited in trial I and the protein intake was somewhat restricted in trial II, the quantities of nutrients allowed the restricted-fed gilts, except for energy, either met or approached the recommended NRC allowances. Consequently, the main variable in all of the trials, regardless of the method of restriction used, was limited-

TABLE 1. AGE AND 154-DAY WEIGHT AT PUBERTY AS AFFECTED BY FEED LEVEL AND BREED

		Full			Restricted			Average		
Trial	Breed	No. gilts	Weight (lb.)	Age (days)	No. gilts	Weight (lb.)	Age (days)	Weight (lb.)	Age (days)	r_{wp}
	CW	10	154	177	26	129	189	142	183	
I	PC	10	166	188	25	116	197	141	192	
	Av.		160	182[a]		122	193			−0.35
	CW	11	157	178	9	117	205	137	192	
II	PC	11	148	178	9	136	184	142	181	
	Av.		152	178[b]		126	194			−0.54
	CW	17	150	206	18	131	203	140	204	
III	PC	19	174	194	19	140	210	157	202	
	Av.		162	200[c]		136	206			−0.14
	CW	9	157	195	24	125	208	141	202	
V	PC	10	176	192	25	139	205	158	198	
	Av.		166	194[d]		132	206			−0.12
	CW	11	150	234	12	134	225	142	230	
VI	PC	12	172	206	11	151	223	162	214	
	Av.		161	220[e]		142	224			+0.27

r_{wp}=correlation between weight at 154 days and age at puberty calculated within breed and feed groups for the year. All averages are unweighted.

Test of significance for the over-all effect of feed level on age at puberty.

[a] 182 vs. 193 ($P=0.05$–0.10).

[b] 178 vs. 194 ($P<0.05$).

[c] 200 vs. 206 ($P=0.05$–0.10).

[d] 194 vs. 206 ($P<0.01$).

[e] 220 vs. 224 ($P>0.10$).

energy intake, restricted-fed gilts being allowed approximately two thirds (60–75%) of the TDN intake of full-fed gilts. Because of this, the data from the different trials were considered together as well as separately in the statistical analyses.

Analysis of variance within trial was performed by the method of weighted means (Snedecor 1956). The method of unweighted means (Snedecor 1956) was used when more than one trial was included in the analysis. In the analysis of covariance, a test for heterogeneity of simple regression was made using subgroup sums of squares and cross-products. Where heterogeneity was not present, simple regressions were calculated by pooling the sums of squares and cross-products for each subgroup in each trial. The numbers of gilts contributing data in the different trials are shown in tables 1 and 2.

TABLE 2. AGE AT PUBERTY AS AFFECTED BY CROSSBREEDING

Breeding group	No. gilts	Age (days)
Chester White	18	210.9
Poland China	7	197.1
Average[a]	..	204.0
Crossbreds[b]	33	182.3

[a] Unweighted average.
[b] Reciprocal cross between the Chester White and Poland China breeds.

Results and Discussion

Growth

As Affected by Feeding Regimen and Breed. The growth of the restricted-fed gilts was significantly retarded as compared to that of full-fed gilts in each trial. Full-fed gilts were 10 to 25% heavier than restricted-fed gilts at 154 days of age (table 1). Over-all analysis of variance of the 154-day weights revealed a significant trial X breed X feed-level interaction, indicating that the differences between the two breeds on the full and restricted levels of feeding were not consistent from one trial to another. The differences between the two breeds were consistent enough, however, to show a significant over-all breed effect when tested against the trial X breed mean square. The Poland China gilts were heavier (averaged over both feeding regimens) than the Chester White gilts in four of the five trials.

Age at Puberty

As Affected by Feeding Regimen, Breed and Individuality. Full-fed gilts attained puberty at an earlier age than restricted-fed gilts in each trial. The differences, averaged over both breeds, ranged from 4.0 days in trial VI to 16.6 days in trial II and were significant or approached significance in four of the five trials (table 1). The unweighted mean analysis showed the over-all effect to be highly significant. These results confirm the findings of Robertson *et al.* (one trial, 1951b), Burger (one trial, 1952) and Haines *et al.* (two trials, 1959) but are not in agreement with those reported by Self *et al.* (2 trials, 1955) and Gossett and Sorensen (one of two trials, 1959). A summary of the results from the individual experiments represented in this study (five trials) and the eight trials cited above revealed results ranging from a significantly lesser age to a significantly greater age at puberty for full-fed gilts as compared to restricted-fed gilts. In the majority of the experiments (10 of 13), however, full-fed gilts reached puberty at an earlier age than restricted-fed gilts.

The variable nature of the results obtained in the different experiments is what might be expected if some unknown factor was confounded with level of feeding in certain of the experiments. An example may have

occurred in those experiments in which a high protein ration was fed and the same ration was used for both high and low plane feeding. The protein intake of high plane gilts may have been too great and resulted in an increased age at puberty. Robertson *et al.* (1951b) found high protein intake to retard the onset of first estrus in swine. The effect of uncontrolled factors, e.g., digestive disturbances, on age at puberty also may be an example. In dairy heifers, Hawk *et al.* (1954) found that scouring delayed age at puberty and Menge *et al.* (1958) showed that the retarding influence of scouring may be independent of its effect on growth rate. Self *et al.* (1955) observed a higher incidence of scouring in high plane gilts than in gilts on the low plane of nutrition.

There did not appear to be any consistent difference in age at puberty between the Chester White and Poland China gilts used in this study (table 1). Similar findings have been reported by Robertson *et al.* (1951a and 1951b) and Self *et al.* (1955).

Upon inspection of the subgroup means (table 1), there appeared to be a difference in the response of the Chester White and Poland China gilts to full and restricted feeding in some of the trials. However, statistical examination showed none of the interactions to be significant. These findings are in agreement with those reported earlier for the same two breeds (Robertson *et al.*, 1951b; Self *et al.*, 1955).

The influence of an individual's somatic development on the age at which puberty is attained was examined by determining the association between 154-day weight and age at puberty. The correlations were negative in trials I, II, III and V and positive in trial VI. This heterogeneity, which is unexplained, prevented pooling of the data and calculation of an over-all, within-group regression. A negative association between growth rate and age at puberty on an individual basis was shown by Warnick *et al.* (1951) (Robertson *et al.* (1951a) (1951b) Self *et al.* (1955) Foote *et al.* (1956).

Whether the lesser age at puberty observed for full-fed gilts in this study could be attributed to their accelerated body development was examined by adjusting the puberal ages of the full- and restricted-fed gilts for the regression of age at puberty on 154-day weight within the trial and breed. This adjustment removed the significance of the difference between the full- and restricted-fed gilts. In this study the earlier age at puberty of the full-fed gilts appears to be explainable, in large part, on the basis of their greater growth rate.

That increased growth rate resulting from genetic factors is not necessarily accompanied by a decreased age at puberty is indicated in the comparison of the ages of puberty of the Poland China and Chester White gilts; the Poland China gilts grew more rapidly than the Chester White gilts but both breeds attained puberty at approximately the same age. Similar findings have been reported for inbred and line-cross gilts (Warnick *et al.*, 1951; Foote *et al.*, 1956). It appears that variation in

age at puberty resulting from genetic factors is not necessarily explainable on the basis of growth rate.

As Affected by Crossbreeding. The gilts in trial IV furnished the data for this part of the puberty study. No significant difference in age at puberty was found between the Chester White and Poland China gilts, but both breeds of gilts attained puberty at a significantly greater age than the crossbred gilts (table 2). The pure-bred gilts averaged 204.0 days of age at puberty as compared to 182.3 days for the crossbred gilts ($P<0.01$). These results confirm the findings of Foote *et al.* (1956). It appears that the inheritance of age at puberty in breed crosses is non-additive.

As Affected by Season of Birth. The Chester White and Poland China gilts in trial IV and comparable gilts (restricted-fed CW and PC gilts)

TABLE 3. AGE AT PUBERTY AS AFFECTED BY SEASON OF BIRTH

		Spring		Fall	
Year	Breed	No. gilts	Age (days)	No. gilts	Age (days)
1955	Chester White	26	188.9	9	205.2
	Poland China	25	196.6	9	184.1
1956	Chester White	18	202.8	18	210.9
	Poland China	19	210.2	7	197.1
Average[a]	Chester White	..	195.8	..	208.0
	Poland China	..	203.4	..	190.1

[a] Unweighted averages.

in trials I, II and III were used to compare the effects of the fall and spring farrowing seasons on age at puberty in two successive years (1955 and 1956). Chester White and Poland China gilts were found to show a differential response to the fall and spring seasons of birth in each year studied. The over-all analysis of variance showed the season X breed interaction to be highly significant. Spring-born Chester White gilts reached puberty 12.2 days earlier than fall-born Chester White gilts, while spring-born Poland China gilts attained puberty 13.3 days later than fall-born Poland China gilts (table 3). The effect of season of birth on age at puberty has not been investigated extensively, but in all species studied except for cattle, animals born in the spring have tended to attain puberty at an older age than animals born in other seasons of the year as shown by Upp *et al.* (1927) in the pullet, Riddle (1931) in the pigeon and dove, Hammond (1925) in the rabbit, Wiggins *et al.* (1950), and Gossett and Sorensen (1959) in the gilt. In contrast, Hawk *et al.* (1954) found that spring-born heifers reached puberty significantly earlier than those born in other seasons. Menge (1959) obtained similar results in outbred

heifers but was unable to show a significant seasonal effect in inbred heifers.

Upon examination of the data available it becomes apparent that considerable more study is needed to establish the effect of season of birth on age at puberty in the different species. The results of this study emphasize the importance of determining the effects on as many different genetic groups within a species as possible, the response of one group not necessarily being indicative of the response of others.

Summary

The effect of restricted feeding, crossbreeding and season of birth on age at puberty in swine was studied in six trials involving 368 gilts.

Full-fed gilts grew more rapidly and attained puberty at an earlier age than restricted-fed gilts. Their earlier age at puberty appeared to be explainable on the basis of their greater growth rates. Poland China gilts grew more rapidly than Chester White gilts but no consistent differences in age at puberty were found for the two breeds. Reciprocal crossbred gilts of the two breeds attained puberty significantly earlier than either parent breed. The effect of season of birth on age at puberty was found to differ for the two breeds; spring-born gilts attained puberty earlier than fall-born gilts in the Chester White breed, while in the Poland China breed the fall-born gilts attained puberty earlier.

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THE NUTRITIVE VALUE OF TIMOTHY HAY AS AFFECTED BY NITROGEN FERTILIZATION [1, 2]

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IN recent years increasing emphasis has been given to evaluating the nutritive quality of grasses grown with varying levels of nitrogen fertilization (Poulton *et al.*, 1957; Chalupa *et al.*, 1959; Bratzler *et al.*, 1959; Markley *et al.*, 1959; Ramage, 1956). This emphasis has been stimulated by the realization that large acreages of grasslands in this country will not consistently support legume stands. From the work reported to date several points seem well established; the first is that grasses fertilized with 100–150 lb. of nitrogen per acre will yield approximately as much dry matter per acre as will legume stands or legume-grass mixtures (Brown, 1957). Studies of the nutritive value of these nitrogen-fertilized forages indicate that they are equal, if not superior, to alfalfa in digestible protein and digestible energy (Poulton *et al.*, 1957; Chalupa *et al.*, 1959). More recently field studies have also shown the value of nitrogen fertilization for improving the yields and maintaining stands of grasses after legumes have been lost from mixed stands.

The purpose of this investigation was to study the effects of nitrogen fertilization on the yield, chemical composition and apparent digestibility of aftermath timothy forage.

Materials and Methods

A five-acre field that had previously fallowed was used for this study. Mechanical and chemical means of weed control were used to help to insure a pure stand. The field was spring-seeded to Climax timothy, and a heavy basic application of calcium, phosphorus and potassium was made to insure an excess of these elements over crop needs. A limited amount of nitrogen was used at seeding to insure good seed establishment. First cutting forage from these areas was discarded because of weed content. The field was then divided into four areas which were treated with 0, 50, 100, and 200 lb. of nitrogen per acre. The aftermath forage was used for these studies on nutritive value. Despite all precautions, a botanical separation revealed that the aftermath forage contained some weeds, especially that from the higher nitrogen applications. The aftermath forage

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was harvested on September 9, 1958. Yields were recorded and calculated to a moisture-free basis.

Digestion studies of a 4x4 Latin square design were carried out with four yearling wether lambs, each weighing approximately 100 lb. Metabolism crates were used similar to those described by Bratzler (1951). The hay was chopped and fed in equal amounts at a level to insure complete consumption (910 gm.). Each trial consisted of a ten-day preliminary and a seven-day collection period. A three-day rest was allowed between trials.

Chemical analysis for moisture, protein, ether extract, crude fiber, and ash was carried out by procedures outlined in A.O.A.C. (1955). Energy was determined with an adiabatic calorimeter. Apparent digestibility of protein, ether extract, fiber, energy and nitrogen-free extract was calculated. Analysis of variance was conducted as described by Snedecor (1956).

Results and Discussion

The yield data demonstrated the value of nitrogen fertilization for increasing production from grass stands. The yields of the aftermath timothy forage on a moisture-free basis were 790, 2060, 2383, and 2517 lb. per acre for plots treated with 0, 50, 100, and 200 lb. of nitrogen, respectively. The 50-, 100-, and 200-pounds-of-nitrogen plots produced, respectively, 2.6, 3.0, and 3.2 times as much forage as the control plot (0 lb. of nitrogen per acre). In another publication from this station Brown (1957) reported annual yields of timothy of 1090, 4520, 5450, 7000, and 7670 lb. of dry matter per acre, when 0, 80, 120, 200, and 360 lb. of nitrogen, respectively, were applied per acre annually. Similar yield responses to nitrogen fertilization have been reported for other grass species (Vincente-Chandler *et al.*, 1959; Lewis and Lang, 1959; Ramage, 1958).

Differences in acre yields of crude protein were greater than those of dry matter in the present study. The acre yields of crude protein were 111, 327, 452, and 521 lb. for the 0-, 50-, 100-, and 200-pounds-of-nitrogen plots, respectively. The 50-, 100-, and 200-pounds-of-nitrogen plots produced 3.0, 4.1, and 4.7 times, respectively, as much crude protein per acre as the control plot. Lodging caused some difficulty in harvesting forage from plots treated with 100 and 200 lb. of nitrogen.

The crude protein content of these hays increased in response to the nitrogen treatments (table 1). Similar responses have been reported by Markley *et al.* (1959), Chalupa *et al.* (1959), Poulton *et al.* (1957) and Bratzler *et al.* (1959). Nitrogen-free extract content decreased markedly with increasing nitrogen fertilization, and ash content tended to increase.

The data show a slight decrease in gross energy content with increasing nitrogen application, which is due in part to the increase in ash content of these forages and the decrease in ether extract.

The apparent digestibility of nutrients are presented in table 1. The apparent digestibility of protein increased with increasing nitrogen fer-

tilization. The coefficient for the 50-pounds-of-nitrogen hay was significantly higher than the control ($P<.05$). The coefficients for the 100- and 200-pounds-of-nitrogen hay indicate a highly significant increase in protein digestibility ($P<.01$) over the control. Other workers have reported similar results (Poulton *et al.*, 1957; Chalupa *et al.*, 1959; Bratzler *et al.*, 1959; Markley *et al.*, 1959). In the present study a significant ($P<.05$) correlation was found between the content of protein and its apparent digestibility at the various nitrogen treatment levels ($r=0.987$).

The apparent digestibility of the nitrogen-free extract decreased markedly with increasing nitrogen application. The decrease in digestibility

TABLE 1. COMPOSITION, DIGESTIBILITY, AND NUTRITIVE VALUE OF NITROGEN-FERTILIZED TIMOTHY AFTERMATH FORAGE

Nitrogen application, lb. per acre	0	50	100	200
Composition, %				
Protein	14.00	15.87	18.96	20.70
Crude fiber	26.68	27.78	27.16	28.09
Ether extract	3.63	3.47	3.56	3.17
Ash	8.65	9.92	9.78	10.36
N-free extract	47.05	42.99	40.56	37.85
Gross energy, Cal. per gm. DM.	4.52	4.49	4.44	4.34
Digestibility, %				
Protein	63.1	66.2	68.5	70.2
Crude fiber	71.8	71.7	69.6	71.0
Ether extract	49.5	49.9	50.7	47.6
N-free extract	66.9	64.1	61.4	58.0
Nutritive value,				
Digestible dry matter, %	64.5	63.2	62.4	61.4
TDN, lb. per 100 lb. DM.	63.5	61.8	60.8	59.8
Digestible energy, %	62.6	62.5	60.2	59.4
Digestible energy, Cal. per gm. DM.	2.8	2.8	2.7	2.6

from adding 50 lb. of nitrogen was statistically significant ($P<.05$) while the decreases from adding 100 and 200 lb. were highly significant ($P<.01$). The reason for these significant decreases is not known. It is possible that the nitrogen fertilization in some way altered the nature of the nutrients included in the nitrogen-free extract fraction, rendering them less digestible.

The coefficients of apparent digestibility of either ether extract or crude fiber did not show any significant differences related to the various nitrogen application levels. The coefficients for crude fiber digestibility were uniformly high, approximately 70%. Similar coefficients of digestibility of crude fiber have been reported by Poulton *et al.* (1956) for nitrogen-fertilized orchardgrass, and by Markley *et al.* (1959) for bromegrass.

The nutritive values of the forages expressed as digestible dry matter, digestible energy, and TDN are presented in table 1. There was a decrease in each value with increasing nitrogen applications. When the digestible energy, expressed in Calories per gram of dry matter, was studied the

difference between treatment 0 and 50 was not significant; however, that between treatment 0 and 100 was statistically significant ($P<.05$) and that between 0 and 200 was highly significant ($P<.01$). This decrease in digestible energy with increasing nitrogen application is a reflection of the significant decreases in the digestibility of the nitrogen-free extract fraction of the forages.

Nitrogen balance was positive for each animal in all treatments. Body weight of the animals was maintained throughout each trial. Some decrease in acceptability of hay was observed with the 100- and 200-pounds-of-nitrogen treatments, due to the greater stemminess of these hays.

The summary of the analysis of variance is presented in table 2. It will be noted that there was a significant animal effect for crude fiber, the ability of one wether to digest crude fiber being significantly low.

TABLE 2. SUMMARY OF THE ANALYSIS OF VARIANCE. MEAN SQUARES

Source of variation	Period effects	Animal effects	Treatment effects	Error
d.f.	3	3	3	6
Digestion coefficients:				
Crude protein	0.333	2.593	37.493**	2.718
Crude fiber	3.210	11.517*	3.963	1.387
N-free extract	3.847	3.367	57.420**	1.918
Ether extract	5.300	14.397	7.060	5.987
Energy	1.507	1.360	10.260	2.628
Digestible energy, Cal. per gm. DM.	3234.500	2289.330	55201.630*	6380.230
TDN lb. per 100 lb. DM.	0.863	5.267	9.523	3.048

* 5% level of probability.
** 1% level of probability.

Summary

Aftermath Climax timothy was fertilized with four levels of nitrogen, 0 (check), 50, 100, and 200 lb. per acre. The dry matter obtained from the 50-, 100-, and 200-lb. levels was, respectively, 2.6, 3.0, and 3.2 times that of the check plot (790 lb. per acre). Ash content of the forage increased slightly with nitrogen application, nitrogen-free extract dropped markedly, gross energy dropped slightly and crude fiber and ether extract remained relatively unchanged. Crude protein of the forage from 0-, 50-, 100-, and 200-lb. levels was 14.0, 15.9, 18.9 and 20.7%, respectively.

Apparent digestibility of protein was significantly greater ($P<.05$) for the 100- and 200-lb. levels than for the check plot. A correlation ($r=0.987$) between crude protein content and apparent digestibility of protein was statistically significant ($P<.05$). With increasing nitrogen application the apparent digestibility of nitrogen-free extract was significantly decreased; crude fiber and ether extract digestibility were unaffected, and dry matter and energy digestibility and TDN values were decreased

slightly. Digestible energy was significantly lower at the 100- and 200-lb. levels.

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ESTIMATES OF GENETIC AND PHENOTYPIC PARAMETERS IN BEEF CATTLE IV. REPEATABILITY OF COW PERFORMANCE [1, 2]

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IT is necessary to have reliable estimates of certain genetic and phenotypic parameters in farm livestock before breeding plans for maximum or optimum improvement can be made. One of the more important of these parameters in beef cattle is repeatability of cow performance with respect to growth rate and grade of calves to weaning. Several important practical questions are involved. Among these are the extent to which the growth rate and grade of the first calf is a permanent characteristic of the cow, and the amount of culling that can safely be done on the basis of the first calf produced. It is often desirable to reduce numbers in the cow herd by culling earlier than the normal calf weaning date. Thus the reliability of the performance of the calf during the first part of the suckling period as an estimate of the future productivity of the cow should be known.

The objectives of the present study were: (1) to obtain estimates of repeatability of birth weight and of growth rates and grades of calves from the same cow from birth to weaning; and (2) to compare several methods of estimating repeatability.

Materials and Methods

Source of Data. The data were collected from the experimental herds of the Virginia Agricultural Experiment Station at Blacksburg and of the Beef Cattle Research Station at Front Royal which is operated cooperatively by the U. S. Department of Agriculture and the Virginia Station.

The cows in the Blacksburg herd were grade Herefords obtained as random samples of heifers from commercial herds or by keeping entire heifer calf crops from the Station herd. Culling in this herd was done only for reproductive failure or permanent injury; none was done on the basis

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of production traits. The calves were produced in a study of the effectiveness of sire selection reported in detail in earlier papers of the series (Kincaid and Carter, 1958; Carter and Kincaid, 1959a, b.) Bulls, selected in equal numbers within breeds for rapid and slow rates of gain on a 168-day feeding test, were mated to random samples of cows. The cows were rerandomized to breeding groups each year without regard to previous grouping. Records were available on 458 calves, the progeny of 103 cows and 38 bulls over a six-year period (1949–54). There were 176 calves sired by 12 Angus bulls, 238 by 22 Hereford and 44 by 4 Shorthorn bulls. The calves were weighed and identified at birth and weighed at weaning (October 1–10). At weaning they were graded as feeder calves by a committee of three or more, each working independently, and the grades averaged for each calf. The grading system used was that adopted by cooperating stations of the Southern Regional Beef Cattle Breeding Project, S-10.

The Front Royal herds were registered Angus, Herefords, and Shorthorns. The Shorthorn herd was transferred from the U. S. Department of Agriculture at Beltsville, Maryland, in the spring of 1949. This herd has been bred essentially as a closed herd with two or more bulls per year since the early 1930's, and was rather uniform in breeding. Considerable selection for production traits had been practiced prior to moving the herd to the Front Royal Station. The Angus and Hereford herds were assembled from a number of sources and were rather diverse in blood lines. Little selection for production traits was practiced in the Front Royal herds during the years covered by this study. All suitable females were retained for breeding as long as servicable in order to obtain sufficient numbers to stock the Station. A total of 1038 calves, born at Front Royal from 1950 through 1956, were available for this study. These consisted of 315 calves from 115 Angus cows, 332 calves from 122 Hereford and 391 from 127 Shorthorn cows.

The calves were weighed and identified at birth. They were again weighed in midsummer, on or about July 1, when the calves averaged about 120 days of age. The calves were graded at this time by a committee of three or more in the same manner as described for the Blacksburg Station. At this time the first selection of the bulls was made. The bull calves were ranked into a high and low half, within breed and line on the basis of an index which gave equal emphasis to growth rate and grade. One-half of the low one-half of the bull calves, chosen at random, were castrated in order to obtain comparisons of the performance of bull and steer calves from midsummer to weaning. All calves were again weighed and graded in the same manner at weaning time in late September or early October.

Adjustment of the Data. The data from the two stations were analyzed separately because of differences in location, management, and breeding of the cattle. The Blacksburg data were adjusted for sex of calf, breed of sire, and gain level of sire, i.e., whether the sire had been selected for

fast or slow gains on feeding test. Least squares estimates of these effects are shown in table 1. Birth weights were adjusted to the basis of a bull calf sired by a high gaining bull by adding 4 lb. to heifers and 2 lb. to all calves by low gaining sires. Daily gains were adjusted to a Hereford basis by subtracting 0.14 lb. per day from Angus sired calves. Differences in daily gain between Hereford and Shorthorn sired calves were negligible. Gains of heifers were adjusted to a steer basis by adding 0.11 lb. per day, and 0.07 lb. was added to daily gains of calves by the low gaining sires. Feeder grades were adjusted by adding 0.4 of a grade point to calves by the low-gaining sires. No other adjustments in feeder grades seemed necessary.

TABLE 1. LEAST SQUARES ESTIMATES AND STANDARD ERRORS OF DIFFERENCES DUE TO SEX OF CALF, BREED OF SIRE AND GAIN LEVEL OF SIRE FOR BIRTH WEIGHT, DAILY GAIN AND WEANING GRADE (BLACKSBURG DATA)

Item	Birth weight	Daily gain birth to weaning	Weaning grade
Sex:			
Males minus females*	4.1± .8	0.11±.02	—.2±.8
Breed of sire:			
Angus minus Shorthorn	1.1±1.5	0.10±.04	0.1±.3
Hereford minus Shorthorn	—1.0±1.4	—.04±.04	—.4±.3
Gain level:			
High minus low gaining sires	1.8± .8	0.07±.02	0.4±.2
Estimate of the mean	69.8±1.4	1.54±.04	11.6±.3

* Birth weight adjustments are bulls minus heifers; other adjustments for sex are steers minus heifers.

Since the Front Royal data were analyzed within breed the only adjustment necessary was for sex of the calf. Steers and heifers were adjusted to the performance of the bull calves. Average differences between sexes by breeds are shown in table 2. Birth weights were adjusted by adding 5 lb. to Hereford heifers and 4 lb. to the birth weights of Angus and Shorthorn heifers. Daily gains to midsummer were adjusted by adding 0.17, 0.17, and 0.07 lb., respectively, to the daily gains of Angus, Hereford, and Shorthorn heifers. Adjustments for daily gains from birth to weaning were made by adding 0.20, 0.24 and 0.14 lb. to the heifers in the same order. Differences in growth rate from midsummer to weaning between the steers and the remaining bulls from the low indexing one-half of the males at midsummer were small. These values are shown in table 2. Adjustments were made only for Shorthorn steers by adding 0.09 lb. per day to their gains from midsummer to weaning. No adjustment was made for grade since the average differences were quite small, 1/6 of a grade or less.

These adjustments are quite similar to those reported by other workers for similar effects. Botkin and Whatley (1953), Gregory *et al.* (1950), Knapp *et al.* (1942), and McCormick *et al.* (1956) observed that birth weights of males exceeded those of females by 4 to 5 lb. Differences in growth rate similar to those found in this study have been reported (Marlowe and Gaines, 1958; McCormick *et al.*, 1956; Hoover *et al.*, 1956; Rollins and Guilbert, 1954; Botkin and Whatley, 1953; Koch, 1951; Koger and Knox, 1947).

Estimation of Repeatability. Six methods or combinations of records were used with the Blacksburg data to estimate repeatability, the object

TABLE 2. AVERAGES BY SEX [a] OF CALF FOR BIRTH WEIGHT AND FOR GAIN AND TYPE SCORE IN MIDSUMMER AND AT WEANING (FRONT ROYAL DATA)

			Midsummer			Weaning		
Sex	No.	Birth weight	No.	Av. daily gain	Type score	No.	Av. daily gain	Type score
		lb.		lb.			lb.	
Angus males	153	64.2	153	1.88	11.1	153	1.89	11.6
Angus females	162	59.7	162	1.70	11.3	162	1.70	12.0
Hereford males	160	70.2	160	1.75	10.9	160	1.77	11.2
Hereford females	172	65.1	172	1.58	11.2	172	1.53	11.5
Shorthorn males	207	70.7	207	1.63	10.1	207	1.65	10.6
Shorthorn females	184	66.6	184	1.56	10.4	184	1.50	11.2
Angus bulls	...	....	...	....	....	37	1.78	10.9
Angus steers	...	....	...	....	....	42	1.78	11.0
Hereford bulls	...	....	...	....	....	42	1.55	10.8
Hereford steers	...	....	...	....	....	34	1.60	10.5
Shorthorn bulls	...	....	...	....	....	49	1.51	10.0
Shorthorn steers	...	....	...	....	....	59	1.42	9.7

[a] Bull and steer comparisons include only those in the low ranking one-half of the bull calves at midsummer grading; one-half of which were castrated and one-half remained as bulls until weaning.

being to compare different methods or combinations of records. The methods were as follows:

A. Intraclass correlation. Cows were placed in groups born in the same year and calving in the same subsequent years. This procedure resulted in a separation of the variance due to age, year, and fecundity from the variance due to "permanent" differences among cows and to random deviations from these (Morley, 1951). There were 23 such groups.

B. Regression. (1) Regression of the record of the second calf on the record of the first. (2) Regression of the average of all subsequent calf records (one or more calves later than the first) on the record of the first.

C. Product-moment correlations. (1) Correlation of the record of the second calf with that of the first. (2) Correlation of the average of all subsequent calf records (one or more later than the first) with the record of the first. The cows were not grouped for calculating the regression and

correlation coefficients as in the intraclass correlation, but were treated as one group.

D. Division of the herd into high and low halves on the basis of first records and obtaining the regression of the second records on the first (Lush, *et al.*, 1941).

The methods used to estimate repeatability from the Front Royal data were intraclass correlation and regression and correlation of the average

TABLE 3. POOLED ANALYSIS OF VARIANCE AND ESTIMATED COMPONENTS OF VARIANCE

Source of variation	D.F.	Mean squares and variance component				
		Birth weight	Daily gain birth to weaning		Grade at weaning	
Blacksburg						
Grade Herefords						
Among cows	75	90.55	0.0470		3.29	
within cows	164	56.09	.0221		1.83	
Cow component	...	10.79	.008		0.457	
			Daily gain birth to		Calf grade	
		Birth weight	Mid-summer	Weaning	Mid-summer	Weaning
Front Royal						
Angus						
Among cows	92	74.63	0.075	0.057	2.81	2.14
Within cows	107	31.68	.028	.022	1.74	1.62
Cow component	...	19.88	.022	.016	0.495	0.241
Hereford						
Among cows	95	78.18	0.091	0.070	2.64	3.39
Within cows	119	40.72	.042	.028	1.54	1.81
Cow component	...	16.65	.022	.018	0.49	0.70
Shorthorn						
Among cows	96	65.92	0.079	0.059	2.90	3.11
Within cows	130	33.46	.040	.023	1.23	1.22
Cow component	...	13.81	.016	.015	0.71	0.80

of subsequent calf records on the record of the first calf. Separate estimates were obtained for each of the three breeds.

The pooled analysis of variance and estimated components of variance from which the intraclass correlations were derived are shown in table 3.

Results and Discussion

Estimates of repeatability of birth weight, rate of gain from birth to weaning, and grade score at weaning for the Blacksburg cows are shown in table 4. Repeatability of birth weight ranged from 0.06 to 0.29 with an average of 0.18 for the six methods used. The lowest value, 0.06, was

TABLE 4. REPEATABILITY ESTIMATES WITH STANDARD ERRORS (BLACKSBURG DATA)

Method	Birth weight	Weaning gain	Weaning grade
Intraclass correlation	0.16**	0.26**	0.20**
Regression 2nd on 1st	.17±.09	.31±.11	.26±.10
Correlation 2nd with 1st	.20±.10	.27±.10	.26±.10
Regression av. subsequent on 1st	.22±.08	.26±.09	.25±.07
Correlation av. subsequent with 1st	.29±.10	.31±.10	.35±.10
Regression 2nd record on 1st	.06	.38	.30
Average	.18	.30	.27

** P<0.01.

obtained by regression of second records on the first toward the herd average and the highest, 0.29, from correlation of first record with the average of subsequent records. Repeatability of gain from birth to weaning ranged from 0.26 to 0.38 averaging 0.30. Here the regression of second record on the first toward the herd average gave the highest value. An average repeatability of 0.27 with a range from 0.20 to 0.35 for weaning grade was found.

Repeatability estimates of the three traits for the Front Royal cows are shown separately by breeds and methods together with the averages in table 5. Estimates for repeatability of birth weight ranged from 0.23 to 0.38 with an average of 0.30. For gain from birth to midsummer the range was wider, 0.24 to 0.59 with an average of 0.41. Estimates for gain from birth to weaning were similar with an average of 0.42 but with

TABLE 5. REPEATABILITY ESTIMATES WITH STANDARD ERRORS (FRONT ROYAL DATA)

Method	Birth weight	Midsummer		Weaning	
		Daily gain	Grade	Daily gain	Grade
Intraclass correlation:					
Angus	0.38**	0.44**	0.22**	0.42**	0.13
Hereford	.29**	.34**	.24**	.39**	.28**
Shorthorn	.29**	.28**	.36**	.39**	.40**
Reg. av. subsequent on 1st:					
Angus	0.31±.11	0.24±.07	0.29±.08	0.38±.08	0.04±.09
Hereford	.23±.10	.58±.09	.21±.07	.55±.11	.22±.08
Shorthorn	.32±.11	.43±.12	.37±.09	.34±.13	.33±.12
Corr. av. subsequent on 1st:					
Angus	0.33±.12	0.41±.11	0.40±.12	0.52±.11	0.06±.13
Hereford	.26±.12	.59±.09	.32±.11	.51±.10	.31±.11
Shorthorn	.33±.12	.41±.11	.44±.11	.31±.12	.32±.12
Av. by breeds:					
Angus	0.34	0.36	0.30	0.44	0.08
Hereford	.26	.50	.26	.48	.27
Shorthorn	.31	.37	.39	.35	.35
General average	.30	.41	.32	.42	.23

** P<0.01.

somewhat narrower range, 0.38 to 0.55. Repeatability of grade at midsummer averaged 0.32 ranging from 0.21 to 0.44. A lower value of repeatability of grade at weaning was found, an average of 0.23 with a range of 0.04 to 0.40.

These estimates are in reasonably close agreement with others reported in the literature. Repeatability of birth weights found in this study, 0.18 for the Blacksburg and 0.30 for the Front Royal data, are fairly close to those reported by others which include estimates of 0.26 by Koch and Clark, (1955); 0.14 to 0.18 by Botkin and Whatley, (1953); 0.24 by Gregory *et al.* (1950); and 0.19 by Knapp *et al.* (1942).

Repeatability of gains from birth to weaning in this study ranged from 0.26 to 0.38 for the Blacksburg data and 0.31 to 0.55 for Front Royal and are of similar magnitude to those found by other investigators. Botkin and Whatley (1953) reported repeatability of gain from birth to weaning to be 0.38 and Gregory *et al.* (1950) reported an estimate of 0.50. Several reports of repeatability of weaning weight adjusted to a standard age (usually 210 days) have been published. Most of these are of the same order as for gain from birth to weaning, and include estimates of 0.34 by Koch and Clark (1955); 0.52 by Koch (1951); 0.43 by Botkin and Whatley (1953); 0.49 to 0.59 by Koger and Knox (1947); 0.50 by Gregory *et al.* (1950); 0.20 by Knapp *et al.* (1942); and 0.38 to 0.68 by McCormick *et al.* (1956).

The values of repeatability of gain from birth to midsummer from the Front Royal data, average 0.41, are essentially the same as for gains from birth to weaning, 0.42. Hoover *et al.* (1956) found repeatability of calf weights at 112 days to be 0.29 and 0.35 by different methods of calculation. In the same study repeatability of 210-day weights were 0.32 and 0.35. In Hoover's study the correlation of 112- and 210-day weights was 0.86. Rollins and Guilbert (1954) reported repeatabilities of 0.34 for four-month weights and 0.48 for 240-day weaning weights.

Repeatability of grade at weaning averaged 0.27 for the Blacksburg calves and 0.23 for the Front Royal calves. Similar estimates of 0.22 and 0.24 were reported by Koch and Clark (1955) and Koger and Knox (1947), respectively. Estimates of repeatability of midsummer grade for the Front Royal calves averaged higher, 0.32, than for weaning grade.

Culling cows on the basis of the growth rate and grade of their calves to midsummer at about 120 days of age appears to be about as accurate as at weaning time. In the Front Royal data repeatability of rate of gain to midsummer was equal to that at weaning and for grade it was equal or higher. It is often desirable from a practical standpoint to reduce a herd at this time because of drought or other reasons.

No essential differences in the estimates obtained by the different methods were apparent. Somewhat lower estimates of repeatability were obtained from intraclass correlation with the Blacksburg data, but there was little difference among the methods in the Front Royal estimates.

The inclusion of subsequent records, at Blacksburg, did not consistently increase the estimates over those in which only the first record was used. This seems rather surprising since the Blacksburg cows averaged over four calves per cow.

Differences in estimates of repeatability of the different traits among the three breeds at Front Royal were small and apparently random except for grade at weaning. Repeatability of weaning grade for the Angus cows was essentially zero although at midsummer repeatability of grade for the Angus was 0.30, intermediate between the Hereford (0.26) and the Shorthorn (0.39). No explanation for this discrepancy is apparent to the authors. The Angus calves at the Front Royal Station had faster growth rate from birth to weaning than the other two breeds. It is possible that this faster growth rate and resulting higher condition at weaning might have obscured some of the differences in type.

In general repeatability estimates from the Front Royal data were higher than those from Blacksburg. The mating systems followed at the two Stations may be a partial explanation. The Blacksburg cows were reassigned to breeding groups at random each year. The bulls to which they were bred were of three breeds and were selected for rapid or slow rates of gain. At Front Royal a considerable proportion of the cows remained in the same herds from year to year. Higher estimates of repeatability might be expected under the Front Royal conditions than at Blacksburg.

Summary and Conclusions

Repeatability estimates were obtained on data collected from a total of 1496 calves from the experimental herds of the Virginia Agricultural Experiment Station, Blacksburg, and the Beef Cattle Research Station, Front Royal. Average repeatability estimates in the Blacksburg herd were 0.18 for birth weight, 0.30 for gain from birth to weaning, and 0.27 for weaning grade. Averaging the methods used over all breeds in the Front Royal data resulted in repeatability estimates of 0.30 for birth weight, 0.41 for gain from birth to midsummer, 0.32 for midsummer grade, 0.42 for gain from birth to weaning, and 0.23 for grade at weaning. Estimates obtained by the different methods of calculating repeatability were in good agreement. Estimates of repeatability obtained at midsummer agreed well with those at weaning, thus allowing for an accurate selection of cows to be made on the basis of growth rate and grade of their calves at a time prior to weaning.

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STABILIZED WHITE GREASE AND CORN OIL IN THE DIET OF BABY PIGS [1]

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INEDIBLE fats are often available for animal feeding and have been shown to be equal or superior to other energy sources for growing-fattening swine (Heitman, 1956; Kropf *et al.*, 1954; Gestler *et al.*, 1957). However, cost and supply are usually such that the consistent widespread use of these fats in market hog rations would be impractical. Hence, such fat might be more advantageously used in specialty rations for other classes of swine such as baby pigs. The dry matter of sows' milk contains approximately 30 to 40% fat. The high level of energy is lowered before or at weaning when a low-fat ration is fed. If gastrointestinal capacity is limiting in early weaned pigs and if they are as able as older pigs to utilize commercial fats, the addition of fat to prestarter and starter rations might be practical and advantageous.

The purpose of this study was to observe the effects of added fat in the rations of young pigs on growth, body fat characteristics and apparent digestibility of fat and protein.

Experimental Procedure

Experiment I. Crossbred pigs 3 to 4 weeks old, averaging 18 lb. in weight, were allotted to four comparable groups of 10 pigs each. The animals were housed in a barn with concrete flooring and were allowed to eat and drink *ad libitum*. A description of the rations fed is given in table 1. The protein-to-energy ratios were held constant. The basal ration was nutritionally adequate and palatable so that comparisons could be made on the basis of differing caloric densities. The pigs were weighed twice weekly, and feed consumption was recorded by lot. At the end of the 40-day period, three animals representing the large, medium and small individuals of each lot were slaughtered to obtain carcass data.

Blood was withdrawn from the anterior vena cava for determination of fat (Allen, 1938) immediately prior to slaughter. Backfat depth and specific gravity were determined on the left side of the carcass. A uniform shoulder-cut from the atlas joint to the 4th rib was taken from the right side, boned out, and the meat homogenized in a silent cutter. The meat was extracted with ether, and iodine number and saponification number determined on the extract. Ether extract and saponification num-

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TABLE 1. INGREDIENTS AND CALCULATED COMPOSITION OF BABY PIG RATIONS

Ration treatment	No added fat	11% grease	16% grease	16% corn oil
Ingredients, lb.				
Sucrose	10.0	7.0	5.0	5.0
Corn	58.0	40.0	31.0	31.0
Grease[a]	....	11.0	16.0	....
Corn oil	....	....	....	16.0
Soybean oil meal	15.0	20.0	23.0	23.0
Tankage	7.5	10.0	11.5	11.5
Dry skimmilk	7.5	10.0	11.5	11.5
Dicalcium phosphate	0.70	0.30	....	....
$CaCO_3$	0.35	0.10	....	....
	plus trace mineralized salt, vitamin mix[b] and antibiotic			
Fat, %	3.8	14.6	19.6	19.6
Protein, %	19.0	22.1	24.1	24.1
TDN, %	79.6	94.6	101.3	101.3
Ca, %	0.94	0.93	0.93	0.93
P, %	0.74	0.76	0.76	0.76
Nutritive ratio	1:3.19	1:3.20	1:3.20	1:3.20
Cal. per gm. protein[c]	18.8	18.9	18.9	18.9

[a] Stabilized white grease from Oscar Mayer and Co., Madison, Wis.
[b] N.R.C. requirements met for all known vitamins.
[c] Using 4.5 Cal. per gm. TDN. (Crampton *et al.*, 1957).

ber were determined by A.O.A.C. (1950) methods, and iodine number by the method of Rosenmund and Kuhnhenn (1923).

Experiment II. The apparent digestibility of ether extract and protein as affected by added fat was determined by the chromic oxide technique (Clawson *et al.*, 1923). Six uniform Poland China littermates, 6 weeks of age, were divided at random into three groups of two. Experimental rations are described in table 3. These rations were fed during a 14-day

TABLE 2. PERFORMANCE, CARCASS DATA, BLOOD FAT AND FAT CONSTANTS OF BABY PIGS

Ration treatment	No added fat	11% grease	16% grease	16% corn oil
Feed per head, lb.	87.4	82.4	76.2	71.7
Gain per head, lb.	33.7	33.6	33.1	28.1*
Feed per lb. gain, lb.	2.6	2.4	2.3	2.6
TDN per lb. gain, lb.	2.06	2.32	2.33	2.58
Blood fat, mg. %	184	231**	269**	287**
Dressing percentage	68.7	65.7	66.9	69.5
Backfat, in.	0.58	0.58	0.73	0.65
Specific gravity	1.059	1.052*	1.053*	1.047*
Fat of shoulder cut, %	19.64	20.65**	22.97**	22.36**
Saponification no.	243	244	242	262*
Iodine no.	60	61	58	77**

* Siginficantly different from controls at $P<0.05$.
** Significantly different from controls at $P<0.01$.

preliminary period before collections began. Feces (90% of total output) were collected during two 96-hour periods separated by a 48-hour rest period. This proceduce was repeated with six littermate Chester White pigs, but only one collection was made. The feces were dried in a forced-air oven at 100° C., ground through a 20-mesh screen in a Wiley mill and mixed for analysis. The feed and feces were analyzed for ether extract and protein by A.O.A.C. methods (1950), and chromic oxide was estimated by the method of Schürch *et al.* (1950).

TABLE 3. INGREDIENTS AND CALCULATED PERCENTAGE COMPOSITION OF RATIONS FOR DIGESTIBILITY STUDIES

Ration	Control	10% fat	20% fat
Corn	74.5	56	36
Grease[a]	....	10	20
Soybean oil meal	14.5	20	27
Meat scraps	8.0	12	15
Brewers' yeast	1.0	1.0	1.0
Chromic oxide	1.0	1.0	1.0
Trace mineral salt	0.8	0.8	0.8
Antibiotic premix	0.1	0.1	0.1
$ZnSO_4$	0.05	0.05	0.05
TDN, %	76.7	91.1	105.7
Protein, %	18.7	21.8	25.0
Nutritive ratio	1:3.1	1:3.2	1:3.2
Cal. per gm. protein[b]	18.5	18.9	18.9

[a] Stabilized white grease from Oscar Mayer and Co., Madison, Wis.
[b] Using 4.5 Cal. per gm. TDN. (Crampton *et al.*, 1957).

Results

Experiment 1. Table 2 shows the results of experiment 1. Pigs fed grease did not gain more than those fed no added fat, while those fed corn oil gained significantly less than those in any of the other lots. Feed and TDN conversion were not determined individually, and the data could not be subjected to statistical analysis. There seemed, however, to be little difference in feed conversion between the pigs fed grease and the control pigs. The ration containing corn oil was less efficiently utilized than any of the other rations. The control lot appeared to be the most efficient in TDN conversion, whereas the corn oil lot was definitely the least efficient. Pigs from the lots fed fat had a lower carcass specific gravity, higher fat content of the shoulder cut and higher blood fat levels than those from the control lot. There was no difference in saponification number or iodine number of body fat between the pigs fed grease and the control pigs, but the saponification and iodine numbers were elevated in those fed corn oil. The statistical significance of these differences is indicated in table 2. There was no significant difference between lots in dressing percentage or backfat thickness.

Experiment II. The results are given in table 4. Added fat increased the apparent digestibility of ether extract and of protein in all three collection periods. There was no difference in effect between the 10% and 20% levels of added fat.

Discussion

The young pig appears to be able to meet its energy requirements quite adequately on a ration containing no added fat. This would suggest that gastrointestinal capacity is not a limiting condition in early-weaned pigs. The corn oil ration was not well utilized in this experiment. One reason for this may have been a low acceptability of the corn oil ration, which had an oily consistency. This was especially true at the beginning

TABLE 4. APPARENT DIGESTIBILITY OF ETHER EXTRACT AND PROTEIN IN CONTROL AND ADDED FAT (GREASE) RATIONS

	Ether extract digestibility, %			Protein digestibility, %		
Pigs and collections	Control	10% fat	20% fat	Control	10% fat	20% fat
Poland China pigs						
1st collection	72	87	89	75	84	82
2nd collection	70	88	90	76	83	81
Chester White pigs	75	87	89	80	84	86
Average	72	88**	89**	77	84**	83**

** Significantly different from controls at $P<0.01$.

of the experiment. For the first 20 days the lot fed corn oil ate considerably less and wasted more feed than the other lots.

The efficiency data are difficult to assess without statistical analysis. Energy conversion, expressed here as lb. TDN per lb. gain, is obviously the more definitive concept when rations of varying caloric density are considered. On this basis the control ration seemed to be more efficiently utilized than the rations with added fat. This difference, however, could be due entirely to some spillage losses of the fat rations.

Although the rations containing grease produced gains comparable to the control ration, there are disadvantages in the use of high levels of grease in swine feeds. Special equipment and care are required for mixing, storage, and the prevention of rancidity in feeds containing over 10% fat. These practical difficulties, though relatively independent of the nutritional value of the feeds, are nevertheless major factors in dietary recommendations.

The blood fat levels of the pigs fed fat were considerably higher than those reported by Self (1959) while the levels of the control pigs were in close agreement with his figures. The elevated blood fat levels are

probably only indicative of active fat absorption from the gut at the time of sampling and may have no other metabolic significance.

The increase of fat deposition in the treated pigs as indicated by lower specific gravity and higher fat content of the shoulder cut was statistically significant. The effect of this increased fat deposition in the young pigs upon their subsequent growth and performance and upon the quality of the carcass at market weight should be considered. It seems, however, that a treatment so far removed from slaughter would have little effect in comparison to a feeding regimen immediately prior to slaughter.

The difference in the composition of the fat of the pigs fed corn oil agrees with the recent observations of Blumer *et al.* (1957), who showed an increase in the iodine number of the fat of pigs fed highly unsaturated oils; soft carcasses were prevented, however, by feeding coconut oil for 30 days prior to slaughter. Thus it is probable that a change in the character of the fat of a baby pig would not affect the type of fat in the carcass if certain feeding practices were followed during the fattening period.

In the digestibility studies, the effect of added fat was an increase in the apparent digestibility of total fat and protein in the resultant rations. The increased apparent digestibility of protein in the high-fat rations is in accordance with the work of Lowrey *et al.* (1958).

Reports on the value of fats in the rations of baby pigs are conflicting. Peo *et al.* (1957) and Hanson *et al.* (1954) report no significant gains attributable to fat in the rations, but Crampton and Ness (1954), demonstrated increased gains when 5% corn oil was added to the diet of baby pigs. The experiments reported here seem to indicate that there is no advantage in adding fat to the rations of baby pigs if the ration fed is palatable and high in available nutrients. However, grease might be used if a sufficient supply at low cost were available and if mixing and storing facilities were suitable. Corn oil seems to have some disadvantage under the conditions reported in the present experiment.

Summary

Forty baby pigs were used in an experiment to determine the value of added grease and corn oil in a baby pig ration high in available nutrients. Pigs fed grease showed no advantage in weight gain, feed efficiency or energy conversion over controls. Pigs fed corn oil gained more slowly and less efficiently than the controls and their body fat had a higher saponification number and iodine number. Higher blood fat, fat content of the shoulder and lower specific gravity of carcass were observed in all groups of fat-fed pigs.

In digestion trials the inclusion of 10% and 20% grease in the rations of 8-week-old pigs increased the apparent digestibility of ether extract and protein.

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THE VALUE OF HAY PELLETS WHEN FED WITH GRASS SILAGE AND MIXED HAY IN WINTERING RATIONS FOR STEER CALVES

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RESEARCH at this station has shown that grass silage and mixed hay of average or lower quality need to be supplemented with concentrates in order to produce efficient gains for wintering steer calves (Miller *et al.*, 1957). Recent research has shown an appreciable advantage for pelleting hays when fed in high roughage rations to steers (Webb and Cmarik, 1957; Weir *et al.*, 1959). The purpose of the three experiments herein reported was to determine the feeding value of hay pellets when furnishing approximately one-fourth the roughage in rations with either grass silage or mixed hay as the major roughage.

Experimental

Animals Used. The steer calves in each experiment averaged between 400 and 475 lb. in initial weight and approximately U. S. Good in feeder grade. Four lots of 12 steers were wintered in each experiment in an open shed with outside paved lots. Steers were evenly distributed between lots according to grade and weight. The length of the experiments was as follows: Experiment I (1956–1957) 151 days; Experiment II (1957–1958) 153 days; and Experiment III (1958–1959) 144 days.

Feeding Plans. In Experiment I two lots (Lots I and III) were full-fed grass silage as the major roughage. Lot I was fed 2 lb. ground shelled corn per head daily, as earlier work had shown the need for at least this amount of grain. Lot III received 3.0 lb. of hay pellets in addition to the grass silage. The other two lots (Lots II and IV) were full-fed mixed hay as the major roughage. Lot II received in addition, 3 lb. of hay pellets. Lot IV was fed baled, mixed hay alone.

The feeding plans for Experiment II and III were similar to those for Experiment I. However, in Experiment II, lower than desired gains were being made by the calves in Lots I, III and IV; therefore, during the last 46 days of the experiment 2.0 lb. of ground corn were fed per head daily as additional feed for each of the four lots. In Experiment III, Lots I and IV, which did not receive alfalfa pellets, were fed 3 lb. of second-cutting baled alfalfa hay per head daily as part of the roughage.

Feeds Used. The hay pellets were made by conventional pelleting equipment but differed appreciably between experiments in forage used and therefore in composition. In Experiment I, the pellets were $\frac{5}{8}$-inch in size made from finely-ground late-season second or third cutting field-cured

TABLE 1. PERCENTAGE COMPOSITION OF FEEDS

Item	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash
Experiment I (1956–57)						
Grass silage (as fed)	29.77	3.41	1.11	11.49	11.61	2.15
Mixed hay	87.82	10.35	2.39	28.75	40.24	6.09
Alfalfa pellets	86.32	16.41	1.94	26.18	33.64	8.15
Corn, ground	86.61	8.95	3.03	1.97	71.40	1.26
Experiment II (1957–58)						
Grass silage (as fed)	29.90	3.31	1.26	11.30	12.14	1.89
Mixed hay	89.95	11.73	1.84	31.90	38.49	5.99
Mixed hay pellets	90.13	12.61	1.59	31.04	38.69	6.22
Corn, ground	86.00	8.70	3.51	2.13	70.42	1.24
Experiment III (1958–59)						
Grass silage (as fed)	24.13	2.65	0.85	9.26	9.64	1.73
Mixed hay	89.56	12.37	1.76	33.04	36.13	6.26
Dehydrated alfalfa pellets	87.23	22.57	3.48	21.78	30.81	8.59
Alfalfa hay	89.18	19.43	1.79	28.15	33.46	6.25
Corn, ground	89.28	9.13	3.32	3.14	72.23	1.46

alfalfa hay. These pellets contained 16.4% total protein and 26% crude fiber.

In Experiment II, the pellets were made on special order at a local mill from average quality first-cutting baled mixed hay containing approximately one-half alfalfa and one-half timothy and other grasses. This field-cured baled hay was ground finely in a portable hammermill (⅛-inch screen) and then processed into ½-inch cubes or pellets. These hay pellets contained 12.6% total protein and 31% crude fiber. The mixed hay for the pellets and the long mixed hay fed in Experiment II were of as nearly the same composition and stage of maturity as could be obtained. Each was rather coarse and stemy.

In Experiment III the hay pellets were of ¾-inch size made from finely ground, artificially dried third-cutting alfalfa. These pellets were definitely the highest in quality as indicated by the fact that they contained 22.6% total protein and 22% crude fiber. As mentioned previously, 3.0 lb. of excellent quality baled alfalfa hay were fed per head daily to the two lots not getting alfalfa pellets (Lots I and IV).

The grass silage and the mixed hay fed in a particular experiment were of the same or similar composition. The grass silage was harvested about 2 weeks earlier than the hay. A forage harvester was used and either approximately 80 lb. molasses were added per ton of green material Experiment I) or approximately 8 lb. of sodium bisulfite were added (Experiment II and III). The mixed hays fed in Experiments I and II were field-cured and baled with a pick-up baler. For Experiment III, the baled hay was partially dried on wagons with a commercial oil-heated drier.

The composition of the feeds is given in table 1.

Results

The results of each of the three experiments are shown in tables 2, 3 and 4.

Discussion

The pellets fed in each experiment were very palatable to the calves. They would leave either the baled long hay in the hay bunk or the grass silage to eat pellets much as cattle will leave hay to get a feeding of grain. While the pellets were limited to 3.0 lb. per head daily, or to about one-fourth the roughage intake, it was obvious that the calves would have eaten more had it been offered them.

In Experiment I, the calves which received mixed hay and alfalfa pellets (Lot II) made the greatest average daily gain of the four lots and required the least dry matter per cwt. gain. The calves fed 3 lb. of alfalfa pellets and grass silage made slightly more gain than those receiving 2 lb. of ground corn with grass silage but there was little difference in the dry

TABLE 2. EXPERIMENT I. THE VALUE OF FIELD CURED ALFALFA PELLETS

Lot and ration	I Grass silage and corn	II Mixed hay and alfalfa pellets	III Grass silage and alfalfa pellets	IV Mixed hay
Av. daily ration, lb.				
Grass silage	29.3	....	28.8	....
Mixed hay	....	12.0	....	14.6
Alfalfa pellets	....	2.9	2.9	....
Ground corn	1.9	....	....	....
Av. daily ration (dry matter), lb.				
Grass silage	8.7	....	8.6	....
Mixed hay	....	10.5	....	12.8
Alfalfa pellets	....	2.5	2.5	....
Ground corn	1.7	....	....	....
Total	10.4	13.1	11.1	12.8
Av. daily gain/steer, lb.	1.09	1.49	1.15	1.16
Total feed/cwt. gain, lb.				
Grass silage	2686	....	2503	....
Mixed hay	....	807	....	1256
Alfalfa pellets	....	195	252	....
Ground corn	178	....	....	....
Total dry matter/cwt. gain, lb.				
Grass silage	800	....	745	....
Mixed hay	....	709	....	1103
Alfalfa pellets	....	168	217	....
Ground corn	154	....	....	....
Total	954	877	962	1103

matter required per cwt. gain. The lot fed mixed hay only (Lot IV) made satisfactory gains but had the greatest dry matter requirement per unit gain. The feeding of 3 lb. of pellets with mixed hay (Lot II) resulted in a greater average daily gain of 0.33 lb. and in 226 lb. less dry matter consumed per cwt. gain than when mixed hay was fed alone.

The data from Experiment II, in which pellets from average quality mixed hay were fed, show that all lots had lower gains and required more

TABLE 3. EXPERIMENT II. THE VALUE OF FIELD CURED MIXED HAY PELLETS MADE FROM BALED HAY

Lot and ration	I Grass silage and corn	II Mixed hay and hay pellets	III Grass silage and hay pellets	IV Mixed hay
Av. daily rations, lb.				
Grass silage	25.3	....	23.4	....
Mixed hay	....	11.3	....	12.7
Mixed hay pellets	....	2.9	2.9	....
Ground corn	2.5	0.6	0.6	0.6
Av. daily ration (dry matter), lb.				
Grass silage	7.6	....	7.0	....
Mixed hay	....	10.2	....	11.4
Mixed hay pellets	....	2.6	2.6	....
Ground corn	2.2	0.5	0.5	0.5
Total	9.8	13.3	10.1	11.9
Av. daily gain/steer, lb.	0.99	1.22	0.92	1.00
Total feed/cwt. gain, lb.				
Grass silage	2561	....	2535	....
Mixed hay	....	932	....	1266
Mixed hay pellets	....	236	314	....
Ground corn	256	47	62	57
Total feed/cwt. gain (dry matter), lb.				
Grass silage	766	....	758	....
Mixed hay	....	838	....	1139
Mixed hay pellets	....	213	283	....
Ground corn	220	40	53	49
Total	986	1091	1094	1188

dry matter per cwt. gain than for Experiment I. Again, the highest gaining lot was Lot II which was fed mixed hay and mixed hay pellets. The gain was 0.22 lb. per head greater than for Lot IV (mixed hay) and the difference in dry matter required per cwt. gain averaged 97 lb. less. This difference was less than observed between the same lots in Experiment I but the hay pellets were of lower quality and considered nearly identical to the long hay that was fed. In this trial, the 2.0 lb. ground corn had a higher feeding value when fed with grass silage than the 3.0 lb. of mixed hay pellets.

All the roughages fed in Experiment III appeared to be of higher feeding value than those fed in the first two experiments. As mentioned previously, an equal amount of top quality baled, field-cured alfalfa hay was fed to the two lots not getting the artificially dehydrated alfalfa pellets and the pellets were of exceptionally high quality. The small amount of mixed

TABLE 4. EXPERIMENT III. THE VALUE OF ARTIFICIALLY DEHYDRATED ALFALFA PELLETS

Lot and ration	I Grass silage and corn	II Mixed hay and alfalfa pellets	III Grass silage and alfalfa pellets	IV Mixed hay
Av. daily rations, lb.				
Grass silage	22.8	....	29.1	....
Mixed hay	0.16	10.6	0.54	10.5
Alfalfa hay	2.9	....	....	3.0
Alfalfa pellets	....	3.0	3.0	....
Ground corn	2.0	....	....	....
Av. daily ration (dry matter), lb.				
Grass silage	5.5	....	7.0	....
Mixed hay	0.14	9.5	0.49	9.4
Alfalfa hay	2.6	....	....	2.7
Alfalfa pellets	....	2.6	2.6	....
Ground corn	1.8	....	....	....
Total	10.0	12.1	10.1	12.1
Av. daily gain/steer, lb.	1.31	1.41	1.41	1.14
Total feed/cwt. gain, lb.				
Grass silage	1737	....	2062	....
Mixed hay	12	753	38	918
Alfalfa hay	218	....	....	264
Alfalfa pellets	....	213	213	....
Ground corn	152	....	....	....
Total feed/cwt. gain (dry matter), lb.				
Grass silage	419	....	498	....
Mixed hay	11	674	34	822
Alfalfa hay	194	....	....	235
Alfalfa pellets	....	164	165	....
Ground corn	136	....	....	....
Total	760	838	697	1057

hay was fed Lots I and III during the short period in which the grass silage was brought to a full feeding.

The two lots of calves getting grass silage as the basal roughage (Lots I and III) made excellent and efficient gains. Comparing the two lots fed mixed hay (Lots II and IV) there was an increase in daily rate of gain of 0.27 lb. for the lot getting the alfalfa pellets (Lot II). The difference in dry matter required per cwt. gain was 219 lb. less for the lot fed the pellets. A similar comparison between Lots I and III (grass silage) shows

a slight advantage in favor of the lot fed 3.0 lb. alfalfa pellets rather than 2.0 lb. ground shelled corn.

Although the three experiments were not replicates, the basic feeds for each lot were the same for each experiment. The three-year averages for rate of gain are as follows: Lot II, 1.37 lb.; Lot III, 1.16 lb.; Lot I, 1.13 lb.; and Lot IV, 1.10 lb. The lots ranked as follows on dry matter required per cwt. gain: Lot I, 900 lb.; Lot III, 918 lb.; Lot II, 935 lb.; and Lot IV, 1116 lb. The significant differences were that calves fed the mixed hay and pellets (Lot II) made the greatest gain in each of the three experiments and the calves fed mixed hay (Lot IV) had the greatest dry matter requirement per cwt. gain for each experiment.

The rate of gain for the calves fed mixed hay and pellets (Lot II) was higher than that made by the calves fed long hay only (Lot IV) by 28%, 22% and 24%, respectively, for the three experiments, or an average of about 25%. In each of the three experiments, Lot II (hay with pellets) produced a statistically significant higher total gain than Lot IV (hay only) when means were compared by Tukey's mean comparison method. On the basis of dry matter required to produce 100 lb. gain, the calves fed pellets (Lot II) required less than those fed long hay (Lot IV) by the amounts of 20%, 8% and 21%, respectively.

It is of interest that the dry matter intake averaged only slightly higher for the calves in Lot II as compared with Lot IV, a significant difference occurring only in Experiment II. The two lots of fed grass silage consumed about the same amount of dry matter but only about 80% as much as the two lots fed hay.

Practical Considerations. The feed replacement or equivalent value of the hay pellets was calculated based on the feed required per 100 lb. gain. The field-cured alfalfa pellets fed in Experiment I had a value per ton equal to 2.3 tons mixed hay (Lots II and IV); or, to 1450 lb. of grass silage plus 1415 lb. ground shelled corn (Lots I and III). Similarly, one ton of the mixed hay pellets fed in Experiment II was equal in value to 1.5 tons of mixed hay; or, to 175 lb. grass silage plus 1235 lb. of ground corn. The dehydrated alfalfa pellets (Experiment III) had a value per ton equivalent to 1.2 tons alfalfa hay plus 0.8 ton mixed hay; or, to approximately 1100 lb. of the alfalfa hay plus 1450 lb. of ground corn.

These data show that the original quality of the forage made into pellets obviously had an important influence on their feeding value. It also seems obvious that the feeding value of the hay pellets was greater than would be expected from long hay. In fact, the values obtained indicate that under the conditions of these experiments the hay pellets may have contributed to the rations about 50% more feeding value than would be expected from comparable long hays.

Summary

A total of 144 feeder steer calves were used in three experiments to determine the value of hay pellets when fed to provide approximately one-fourth the roughage in wintering rations. Either mixed hay or grass silage was full-fed as the major roughage in the rations. All the pellets were made from finely-ground forage by conventional pelleting machines. The original forages that were pelleted were as follows: Experiment I, field-cured, second- or third-cutting alfalfa; Experiment II, average quality first-cutting, field-cured baled mixed hay with about 50% alfalfa; and Experiment III, artificially dehydrated third-cutting alfalfa.

When fed with average quality mixed hays, the lots receiving 3.0 lb. of pellets made the greater gains in each experiment, averaging about 25% greater for the three experiments than the lots fed long hay without pellets. The amount of dry matter required per 100 lb. gain was less for the calves fed the pellets plus mixed hay than for those fed long hay, ranging from 8% to 21% less. When fed with grass silage 3.0 lb. of the alfalfa pellets were fully equal in feeding value to 2.0 lb. ground shelled corn. The pellets made from baled, field-cured mixed hay were of somewhat lower value.

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RELATIONSHIP BETWEEN SLAUGHTER AND CARCASS GRADES IN BEEF CATTLE [1, 2]

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CATTLE feeders commonly "top off" animals believed ready for market and continue to feed the remainder. The purposes of this study were to determine the accuracy with which carcass grade can be estimated from slaughter grade and to ascertain the relationships among degree of marbling, carcass grade, and carcass conformation.

Materials and Methods

Members of the Department of Animal Husbandry independently graded, to the nearest third of a U.S.D.A. grade, 688 Hereford slaughter cattle fed in 15 experimental groups. Each group consisted of all heifers or all steers and included 2 to 8 lots with 10 animals per lot. No group was graded by all 12 graders; graders per group ranged from 3 to 10 and averaged 6.6.

The animals were approximately 20 to 22 months old when slaughtered; they had been fed fattening rations from 100 to 154 days prior to slaughter.

Carcass data were obtained at packing plants. After cooling 24 to 48 hours, each carcass was graded to the nearest one-third of a grade by an official of the Federal Grading Service. Conformation grades were determined for 254 carcasses, and grades before ribbing were obtained for 430 carcasses. Conformation grade was based on the form or dimensions of the carcass; whereas, carcass grades before ribbing were influenced by conformation, fat covering, interior fat in the pelvic cavity, fat over the kidney, and feathering. Grades after ribbing and degree of marbling in the cross-section of the longissimus dorsi between the 12th and 13th rib were designated for all carcasses. Conformation, finish, degree of marbling, and other quality factors determined grade after ribbing.

Simple correlations between traits were computed. When grades after ribbing were statistically different between lots within a group, the correlations were computed on a within lot basis. Correlation coefficients for the different groups were averaged by use of the "z" transformation.

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[2] The authors express their appreciation to the members of the Animal Husbandry Department, and members of the U.S.D.A. Federal Grading Service for making the data available.

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Results and Discussion

Slaughter and Carcass Grades. Correlations between average slaughter grade and carcass grade (table 1) were considerably lower than the .69 reported by Cook *et al.* (1951) for steers fed to 900 lb. and the .52 published by Woodward *et al.* (1954) for steers fed 252 days. No marked differences in ability of the animal husbandmen to grade cattle were demonstrated, though the graders differed widely in experience and training. Repeatability of slaughter grade (correlation between slaughter grades given the same animal by different graders) was calculated for each group

TABLE 1. WEIGHTED AVERAGE CORRELATIONS[a] BETWEEN SLAUGHTER GRADE AND CARCASS GRADES

	Conformation		Before ribbing		After ribbing	
Grader	r	d.f.	r	d.f.	r	d.f.
A	0.39	99	0.38	237	0.18	433
B	.56	144	.39	259	.24	377
C	.40	197	.28	267	.17	515
D	.46	197	.32	363	.19	611
E	.45	152	.31	310	.19	458
F	.39	98	.35	189	.16	263
G	.23	98	.29	240	.11	340
H	.51	145	.33	287	.18	335
I	.45	244	.29	349	.14	397
J	...	...	.55	57	.39	57
K	.43	98	.28	177	.07	229
L	.40	234	.39	252	.29	304
Av. sl. grade	.56	244	.38	410	.22	636

[a] All correlations are significant at the .01 level except .23, .11, and .07. Only .07 is not significant at the .05 level.

of cattle and the weighted average of the intraclass correlations was .50, based on 657 degrees of freedom.

Eighty-one percent of the carcasses after ribbing were graded within the range average good to average choice. Only one carcass graded as low as average standard and only two graded as high as low prime. Perhaps correlations between slaughter and carcass grades would be higher among cattle more variable in grade. However, these cattle and rations were believed to be representative of those used in many Kansas feedlots. The results clearly show that accuracy in identifying cattle that yielded the higher grading carcasses was quite low.

Relationships between slaughter grade and carcass grades, in decreasing order, were carcass conformation, carcass grade before ribbing, and after ribbing (table 1). These associations were expected because live animal conformation and finish (which more nearly determine carcass conformation and carcass grade before ribbing) should be more accurately evalu-

ated than quality factors that more generally determine grade after ribbing.

Degree of Marbling and Carcass Grades. The three lowest group correlations between carcass grade after ribbing and degree of marbling (.65, .73 and .33) represented a different population correlation from that for the other 12 group correlations, so were not included in the weighted average correlation in table 2. Correlations .65 and .73 were for the first two groups of cattle graded. They were graded a year before the next group, possibly by a different government grader who placed less emphasis on degree of marbling.

Carcasses for which the correlation between grade after ribbing and degree of marbling was only .33 were the only ones graded by one federal grader. The exceptionally low correlation likely resulted from the extreme uniformity of grades and marbling scores given to these carcasses. Forty-

TABLE 2. WEIGHTED AVERAGE CORRELATIONS[a] BETWEEN CARCASS GRADES AND BETWEEN CARCASS GRADES AND DEGREE OF MARBLING

	Before ribbing		After ribbing		Degree of marbling	
Item	r	d.f.	r	d.f.	r	d.f.
Conformation	0.42	244	0.25	244	0.25	244
Before ribbing	...	...	.53	410	.45	410
After ribbing	...	...	...	...	.89	484

[a] All correlations are significant at the .01 level.

one of 50 carcasses received an after ribbing grade of high good, and 45 had either small or slight amounts of marbling.

Unfortunately, names of carcass graders were not recorded. Results of at least four government graders were included.

The high average correlation (.89) between degree of marbling and grade after ribbing indicates the extent degree of marbling was emphasized in determining carcass grade after ribbing.

There are certain disadvantages of ribbing all beef carcasses before they are graded. Nevertheless, the comparatively low average correlations of .45 between carcass grade before ribbing and degree of marbling and .53 between grades before and after ribbing indicate that grade before ribbing has comparatively small value in predicting degree of marbling and carcass grade after ribbing.

Summary

Members of the Department of Animal Husbandry at Kansas State University independently graded 688 Hereford heifers and steers to the nearest one-third of a grade just before they were slaughtered. Each

carcass was graded to the nearest one-third of a grade by an official of the U.S.D.A. Federal Grading Service. Eighty-one percent of the carcass grades after ribbing ranged from average good to average choice.

Weighted average correlations between slaughter grade and carcass conformation ranged from .23 to .56. All were statistically highly significant except the .23, which was significant. All average correlations (which ranged from .28 to .55) between slaughter grade and carcass grade before ribbing were highly significant. Average correlations between slaughter grade and carcass grade after ribbing ranged from .07 to .39. All but two were highly significant and only .07 was nonsignificant. Repeatability of slaughter grade was .50.

Weighted average correlations between carcass conformation and carcass grade before ribbing, after ribbing, and degree of marbling were .42, .25, and .25, respectively. Correlations between carcass grade before ribbing and after ribbing averaged .53. Those between carcass grade before ribbing and degree of marbling averaged .45. Average correlation between carcass grade after ribbing and degree of marbling was .89.

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PREDICTING TOTAL CARCASS LEAN IN MATURE BEEF FROM WEIGHTS OF CERTAIN ENTIRE MUSCLES [1]

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THE amount of lean in a carcass is of particular importance in sire testing programs and in studies of carcass evaluation and of consumer preference for a certain cut of beef. Physical separation of the entire carcass is laborious and costly. Therefore, a simple indirect method for predicting total carcass lean, incurring little or no monetary loss to the carcass, would be extremely useful. Hirzel (1939), Palsson (1939), Branaman (1940) and McMeekan (1941) have reported that the area or the "shape index" of the *Longissimus dorsi* is a good index of total muscling in sheep and swine. Working with beef carcasses, Cole, Orme and Kincaid (1959) found that loin eye area was associated with only 18% or less of the variation existing in total separable carcass lean. The amount of lean in a particular joint or wholesale cut, on the other hand, has been found highly related to total carcass muscling in lambs (Palsson 1939), hogs (McMeekan 1941), and beef cattle (Cole, Orme and Kincaid 1959). The physiological relationship of certain muscles to total carcass muscling has been investigated by few workers. McMeekan (1941) reported the weight of the *Psoas major* muscle in hogs to have a correlation coefficient of 0.814 with the weight of carcass lean. Orme (1958) found that the weight of the *Psoas major* and *Semitendinosus* muscles was not highly correlated with the area of loin eye.

This study was undertaken to determine the validity of using the weight of an individual muscle or a group of muscles to predict total carcass separable lean in mature beef cattle.

Materials and Methods

Six individual muscles and two groups of muscles were excised from the left side of the carcasses of 43 mature (8½ to 11 years) Hereford cows. These cattle were chosen because of their age and because they were accessible for experimentation. They had presumably attained full muscle and

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bone development. This afforded the opportunity to study the relationship of the weight of certain individual muscles to the total lean of the carcass, the effects of age or maturity being somewhat removed. The average weight of the left side of the carcasses was 279 lb.; it ranged from 191 to 405 lb. The live animal weight ranged from 825 to 1410 lb., and the U.S.D.A. carcass grades ranged from high cutter to high commercial. The six muscles excised in entirety included the *Biceps femoris,* (largest outside round muscle), *Semitendinosus,* (eye of the round), (*Psoas major,* (tenderloin), *Longissimus dorsi,* (loin eye or ribeye muscle), *Infraspinatus,* (clod) and *Triceps brachii.* In addition to the six individual muscles, two muscle groups were also excised. These included the major muscles of the inside round, namely the *Semimembranosus* and *Adductor,* and the principal muscles of the sirloin tip, which included the *Vastus lateralis, Vastus intermedius, Vastus medialis* and *Rectus femoris.* Each of the above muscles and muscle groups was excised in its entirety from the left side of each carcass, cleaned of all surrounding fat, and weighed. The remaining lean, fat and bone from each left side was physically separated. Separable carcass lean and bone were weighed, whereas separable fat was obtained by subtracting the sum of the lean and bone from the weight of the whole side of beef. The four smallest muscles, (*Semitendinosus, Psoas major, Infraspinatus* and *Triceps brachii*) were weighed to the nearest gram and later converted to pounds. For the remaining muscles and muscle groups, carcass lean and bone were weighed to the nearest 0.1 lb.

Correlation and regression techniques were used as outlined by Snedecor (1956) to analyze data.

Results and Discussion

The average weight and standard deviation for each of the individual muscles and muscle groups under study and for the three carcass components are listed in table 1. The *Longissimus dorsi, Biceps femoris* and inside round group muscles were the heaviest of those studied and were similar in weight. The *Psoas major, Semitendinosus* and *Infraspinatus* were the lightest, and also similar to one another in weight. The *Longissimus dorsi* muscle was the heaviest of all muscles studied, comprising the highest percent (6.83) of the total separable carcass lean. The lightest muscle, the *Psoas major,* comprised only 2.27% of the total separable carcass lean (table 1). The largest standard deviation for the various carcass components (lean, fat and bone) was found for separable carcass fat. This was explained by the fact that many carcasses possessed an adequate amount of finish to qualify for the prime, choice and good grades if they had come from young cattle. The weight of bone, over the entire range of weights studied, was the most consistent (standard deviation of 3.68) of all carcass components (table 1).

The simple correlation coefficients between separable carcass lean and the weights of the various individual muscles or muscle groups are

TABLE 1. AVERAGE WEIGHTS, STANDARD DEVIATIONS, PERCENT OF THE AVERAGE SEPARABLE CARCASS LEAN AND PERCENT OF THE AVERAGE CARCASS WEIGHT OF THE VARIOUS MUSCLES AND MUSCLE GROUPS

Item	Average weight, lb.	Standard deviation, lb.	Percent of average separable carcass lean	Percent of average carcass weight
Longissimus dorsi	10.97	1.64	6.83	3.93
Biceps femoris	10.49	1.46	6.54	3.76
Inside round muscle group (*Semimembranosus*+*Adductor*)	10.45	1.21	6.51	3.75
Semitendinosus	3.72	.60	2.32	1.33
Sirloin tip muscle group (*Vastus lateralis*+*Vastus intermedius*+*Vastus medialis*+*Rectus femoris*)	8.87	1.08	5.53	3.18
Psoas major	3.65	0.41	2.27	1.31
Triceps brachii	5.18	0.70	3.23	1.86
Infraspinatus	3.93	0.57	2.45	1.41
Other lean	103.25	13.11	64.32	37.02
Total carcass lean	160.51	18.63	100.00	57.46
Total carcass fat	76.85	46.31	.....	27.52
Total carcass bone	41.95	3.68	.....	15.02

TABLE 2. SIMPLE, MULTIPLE CORRELATION AND STANDARD PARTIAL REGRESSION COEFFICIENTS OF CERTAIN INDIVIDUAL MUSCLES AND MUSCLE GROUPS WITH SEPARABLE CARCASS LEAN, SLAUGHTER WEIGHT AND CHILLED CARCASS WEIGHT

	r[a]			b′		R[c]	
Y	Carcass lean (X_1)	Slaughter weight (X_2)	Carcass weight (X_3)	$b'_{x_1y_1 \cdot x_3}$[d]	$b'_{x_1y_1 \cdot x_2}$[e]	X_1 with X_3 and Y_1	X_1 with X_2 and Y_1
Longissimus dorsi	0.92	0.82	0.83	0.79	0.78	0.92	0.92
Biceps femoris	.96	.85	.83	.97	.92	.96	.96
Inside round muscle group (*Semimembranosus*+*Adductor*)	.92	.75	.75	.72	.71	.94	.94
Semitendinosus	.83	.65	.73	.54	.51	.90	.88
Sirloin tip muscle group (*Vastus lateralis*+*Vastus intermedius*+*Vastus medialis*+*Rectus femoris*)	.93	.82	.70	.82	.71	.93	.96
Psoas major	.82	.60	.58	.53	.53	.91	.92
Triceps brachii	.84	.66	.75	.55	.53	.91	.89
Infraspinatus	.80	.75	.72	.44	.43	.86	.87
Slaughter weight	.81						
Carcass weight	.81						

[a] .393 required for significance at P .01.
[c] .454 required for significance at P .01.
[d] Standard partial regression coefficient of total separable carcass lean on the weight of various muscles when slaughtered weight is held constant.
[e] Standard partial regression coefficient of total separable carrass lean on the weights of various muscles when chilled carcass weight is held constant.

listed in table 2. All relationships were highly significant. The weights of the muscles studied were associated with 64 to 92% of the variation existing in the weight of the total separable carcass lean. Correlation coefficients of 0.96, 0.93, 0.92 and 0.92 were obtained between the weight of total separable carcass lean and the weight of *Biceps femoris,* muscles of the sirloin tip, muscles of the inside round, and *Longissimus dorsi,* respectively. The weight of the *Psoas major* muscle was associated with 67% of the variation which existed in carcass lean.

Slaughter and chilled carcass weights were each equal to the weight of the four smallest muscles in predicting total separable carcass lean (table 2).

The simple correlation coefficients between the weights of the various muscles and muscle groups and either slaughter weight (live animal weight) or chilled carcass weight were all highly significant, accounting for 36 to 72% of the variation which existed in either slaughter or carcass weight (table 2). The *Longissimus dorsi, Biceps femoris* and the major sirloin tip muscles were more closely associated with the weight of the live animal than were the other muscles. Similarly, the *Longissimus dorsi* and *Biceps femoris* were most closely related to the weight of the carcass.

The standard partial regression coefficients ($b'_{x_1 x_1 \cdot x_2}$ and $b'_{x_1 x_1 \cdot x_3}$) are listed in table 2. With the exception of the *Biceps femoris* muscle, which increased slightly from 0.96 to 0.97, the standard partial regressions with the live animal weight constant ($b'_{x_1 x_1 \cdot x_2}$) were smaller than their respective simple correlation coefficients; whereas, without exception, with the effects of carcass weight eliminated ($b'_{x_1 x_1 \cdot x_3}$), all relationships between carcass separable lean and the weights of the various muscles or muscle groups were lower than their respective simple correlation coefficients. Estimation of total separable carcass lean was not enhanced by using multiple correlation coefficients since multilinear correlation coefficients were about equal to or slighlty higher than the simple correlation coefficients between carcass lean and muscle mass (explaining 73 to 92% of the variation existing in total carcass lean).

Use of the weight of a particular muscle to estimate the total lean in carcasses from mature beef cattle seems logical and profitable for two reasons. First, the relationships existing between the individual muscle weights and total lean were sufficiently high in most cases for predictive purposes. Second, beef ham sets and tenderloins are commonly merchandised advantageously. Therefore, such muscles as the *Biceps femoris,* principle muscles of either the sirloin tip or inside round, *Semitendinosus* and *Psoas major* would be available for such purposes, incurring little monetary loss. This would be especially true of the *Psoas major* (tenderloin) whose source is largely from mature beef carcasses. The relationships found with these mature cattle that varied greatly in the amount of muscling are suggestive of similar relationships for immature cattle which vary greatly in the amount of muscling.

TABLE 3. REGRESSION OF SEPARABLE CARCASS LEAN ON THE WEIGHT OF CERTAIN MUSCLES OR MUSCLE GROUPS

Muscle	Regression equation[a]	σe
Longissimus dorsi	$\hat{Y}=47.36+10.24\,x$	7.37
Biceps femoris	$\hat{Y}=30.87+12.36\,x$	5.52
Semimembranosus+Adductor	$\hat{Y}=10.95+14.31\,x$	7.54
Semitendinosis	$\hat{Y}=65.00+25.65\,x$	10.60
Vastus lateralis+ Vastus intermedius+ Vastus medialis+ Rectus femoris	$\hat{Y}=16.20+16.27\,x$	6.96
Psoas major	$\hat{Y}=25.64+36.95\,x$	10.92
Triceps brachii	$\hat{Y}=29.40+25.31\,x$	10.27
Infraspinatus	$\hat{Y}=57.62+26.18\,x$	11.56

[a] Equation for *Longissimus dorsi* based on 40 degrees of freedom; all others based on 41 degrees of freedom.

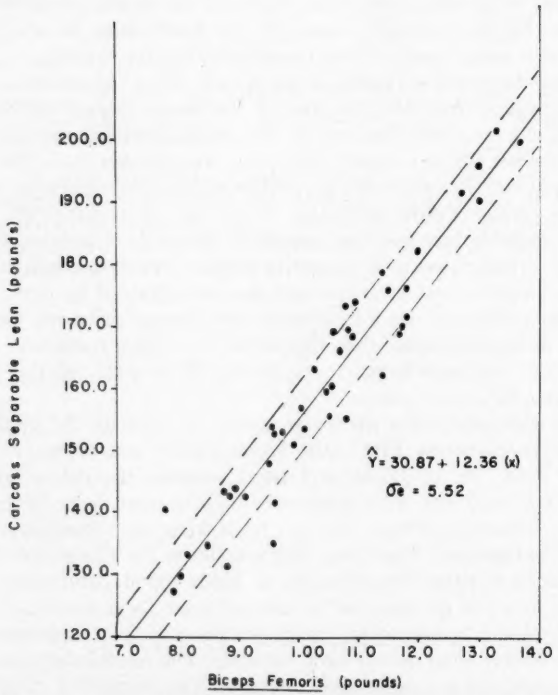

Figure 1. Regression of separable carcass lean on the weight of the Biceps femoris muscle.

The linear regression of the weight of total separable lean on the weights of different muscles (table 3) showed highly significant trends for all eight independent variables. The fraction of the total sum of squares for separable lean in the carcass associated with the single degree of freedom for linear regression ranged from 63% to 91%. The four heavier muscles appear to be the best estimators, but the four lighter muscles also account

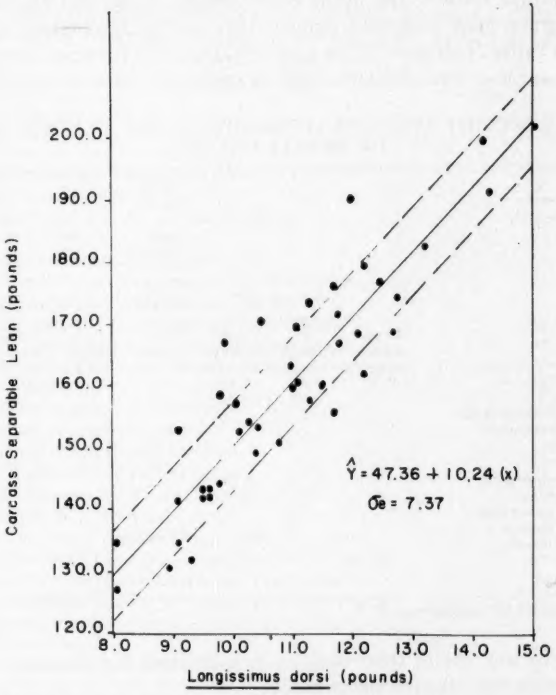

Figure 2. Regression of separable carcass lean on the weight of the Longissimus dorsi muscle.

for a large fraction of the variation in total lean. Figures 1 and 2 show the individual observations for separable carcass lean and their respective linear regressions on the weight of the *Biceps femoris* and the *Longissimus dorsi* muscles, respectively.

The use of the weight of the *Longissimus dorsi* muscle for estimating carcass lean may not have much practical value because it will rarely be feasible to excise this particular muscle in its entirety. However, the standard error of the estimating equation which uses the weight of this muscle indicates its usefulness if its mass could be estimated with precision

by some other method. Since parts of the *Longissimus dorsi* muscle are included in the cut (9–10–11 rib section) most commonly used for carcass evaluation, perhaps a combination of cross sectional areas and linear measurement could be used to estimate its mass. Previous work (Cole, Orme and Kincaid 1959) indicated that area of loin eye at the 12th rib was not by itself a precise indicator of weight of carcass lean.

The *Biceps femoris,* the inside round muscle group and the sirloin tip muscle group each comprises samples that are easily obtained from carcasses of cattle of all ages. If the anatomical relation between these muscles and carcass lean were similarly high in immature cattle, it would be possible to use any one of these muscles in estimating the amount of carcass lean in cattle regardless of age or grade.

TABLE 4. WEIGHT INTERRELATIONSHIPS AMONG CERTAIN MUSCLES OR MUSCLE GROUPS [a]

Item	*Biceps femoris*	*Semimembranosus* + *Adductor*	*Semitendinosus*	*Vastus lateralis* + *Vastus intermedius* + *Vastus medialis* + *Rectus femoris*	*Psoas major*	*Triceps brachii*	*Infraspinatus*
Longissimus dorsi	0.90	0.88	0.80	0.80	0.70	0.77	0.78
Biceps femoris	...	.91	.78	.85	.76	.79	.83
Inside round muscle group (*Semimembranosus*+ *Adductor*)	...	...	.81	.84	.82	.76	.71
Semitendinosus	...	...	...	.66	.70	.77	.55
Sirloin tip muscle group (*Vastus lateralis*+ *Vastus intermedius*+ *Vastus medialis*+ *Rectus femoris*)	...	...	...	...	.72	.66	.75
Psoas major	...	...	...	...	...	.65	.55
Triceps brachii	...	...	...	...	...	...	.73

[a] .393 required for significance at P .01.

The standard error of the regression equations obtained with *Semitendinosis, Psoas major, Triceps brachii* and *Infraspinatus* muscles gave similar results, but the weights of these muscles were less precise indicators of the weight of carcass lean than the other four.

Weight interrelationships between certain entire muscles and muscle groups, are listed in table 4. The weights of all muscles were highly related to each other. Although high relationships between muscle weights were obtained, they were not equally related to one another. The correlation coefficients ranged in magnitude from 0.55, between the weight of the *Infraspinatus* muscle and either the *Semitendinosus* or *Psoas major* muscles, to 0.91 between the weight of the *Biceps femoris* muscle and the *Semimembranosus* and *Adductor* muscles.

In a further attempt to predict total carcass lean from the weights of entire muscles, the weights of various muscle combinations were studied. These relationships are listed in table 5. Seventy-seven to 94% of the variation in total carcass lean was found to be associated with the combined weights of two or more of the muscles studied. With the exception of

TABLE 5. SIMPLE CORRELATION COEFFICIENTS OF SEPARABLE CARCASS LEAN WITH CERTAIN ENTIRE MUSCLES AND MUSCLE GROUP COMBINATIONS

Combined weight of	Total separable carcass lean[a]
Inside round[b] and *Biceps femoris*	0.95
Inside round and *Longissimus dorsi*	.94
Inside round and sirloin tip[c]	.92
Biceps femoris and *Longissimus dorsi*	.96
Biceps femoris and Sirloin tip	.94
Longissimus dorsi and Sirloin tip	.93
Inside round and *Biceps femoris* and *Longissimus dorsi*	.96
Inside round and *Biceps femoris* and Sirloin tip	.95
Inside round and *Longissimus dorsi* and Sirloin tip	.94
Biceps femoris and *Longissimus dorsi* and Sirloin tip	.95
Inside round and *Biceps femoris* and *Longissimus dorsi* and Sirloin tip	.96
Psoas major and *Semitendinosus*	.89
Psoas major and *Infraspinatus*	.92
Psoas major and *Triceps brachii*	.91
Semitendinosus and *Infraspinatus*	.92
Semitendinosus and *Triceps brachii*	.89
Infraspinatus and *Triceps brachii*	.88
Psoas major and *Semitendinosus* and *Infraspinatus*	.95
Psoas major and *Semitendinosus* and *Triceps brachii*	.92
Psoas major and *Infraspinatus* and *Triceps brachii*	.93
Semitendinosus and *Infraspinatus* and *Triceps brachii*	.93
Psoas major and *Semitendinosus* and *Infraspinatus* and *Triceps brachii*	.95
Combined weight of six muscles and two groups	.97

[a] .393 required for significance at P=.01.
[b] Inside round includes: *Semimembranosus* and *Adductor* muscles.
[c] Sirloin tip includes: *Vastus lateralis, Vastus intermedius, Vastus medialis* and *Rectus femoris* muscles.

several combinations involving either the *Biceps femoris* muscle or the muscles included in the sirloin tip, the simple correlation coefficients between the combined weights of the various muscles and total carcass lean were higher than the simple correlation coefficients between the respective individual muscles and carcass lean. However, all relationships implicating the four largest muscles were not improved greatly by combination, due to their high singular relationships. On the other hand, the relationships of the four lightest muscles (*Semitendinosus, Psoas major, Triceps brachii* and *Infraspinatus*) with total carcass lean were particularly improved by

combination. For instance, 90% of the variation in total separable lean was associated with the combined weight of the *Psoas major, Semitendinosus* and *Infraspinatus* muscles. The combined weight of all eight muscles studied was associated with 94% of the total variation existing in separable carcass lean.

Summary

The weights of eight muscles or muscle groups, excised from the left side of the carcasses of 43 mature Hereford cows, were used to derive an estimate of total carcass lean. The standard deviation for the individual muscles ranged from 0.41 to 1.64 lb. of lean as compared to 18.63 lb. for total carcass lean. Sixty-four to 92% of the variation in total separable carcass lean of mature cattle was associated with the weight of certain entire muscles. With slaughter weight held constant, the standard partial regression coefficients obtained between the weight of the total carcass lean and the weight of certain muscles or muscle groups were: *Biceps femoris,* 0.97; sirloin tip muscle group, 0.82; *Longissimus dorsi,* 0.79 and inside round group, 0.72. The regressions of total carcass lean on the weight of the *Biceps femoris, Longissimus dorsi* and the major muscles in the sirloin tip or inside round were 12.36, 10.24, 16.27 and 14.31 lb. of lean, respectively. High interrelationships were found among the weights of all muscles studied. The results indicate the validity of using the weight of certain entire muscles to estimate the degree of muscling in a particular mature beef carcass.

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SUSTAINED PREVENTION OF BLOAT BY FEEDING ANTIBIOTICS IN ROTATION OR IN COMBINATION [1]

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ADMINISTRATION of antibiotics, although a relatively new approach to bloat prevention, offers considerable promise if the decrease in effectiveness of the preventive after a relatively short period (1 to 2 weeks) of successful use can be overcome. Such decreases have been observed by several workers (Barrentine *et al.*, 1958; Brown *et al.*, 1958; Emery *et al.*, 1958a; Johnson *et al.*, 1958a, 1958b; Mangan *et al.*, 1959) and are thought to be due to the development of resistant strains of bacteria or to changes in the balance of the ruminal microflora. Johnson *et al.* (1958a) found that resistance to erythromycin could not be reversed by withholding the antibiotic for periods up to 26 days. Mangan *et al.* (1959) reported that the effectiveness of penicillin was regained when it was withheld for 2 months. The latter observation suggests the possibility of feeding several antibiotics in succession and repeating them after resistance has subsided.

The present experiment was undertaken to test two possible methods of sustaining the effectiveness of antibiotics—feeding several antibiotics in rotation, or feeding them in combinations, with the hope that synergistic combinations might extend the duration of effectiveness.

Experimental Procedure

During the 1959 pasture season, 45 dairy and beef cattle were utilized for grazing trials. Six of these were fistulated steers used for bacteriological studies and antibiotic assays. All animals grazed together on relatively pure second-year alfalfa twice daily, from 7 to 10 a.m. and from 4 to 7 p.m. A rotational grazing plan was followed on a 19-acre field divided into seven plots approximately equal in size. Between grazing periods the animals were maintained in a holding pen in one corner of the field; fresh water and trace-mineral salt were always available in the holding pen.

Each animal received 1.5 lb. of grain prior to each of two daily grazing periods. Antibiotics were administered to the treatment groups in the afternoon grain allowance. The animals were observed continuously during and subsequent to each grazing period for a total of 4 hours. Evaluation was visual, using the scale proposed previously (Johnson *et al.*, 1958a). The maximum bloat score for each animal for each hour was recorded.

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The average of all these scores (eight per day) for all animals in a group constituted the "daily average bloat severity". The highest of the eight scores for each animal was designated maximum; the average of these maxima for all animals in a group was defined as the "daily average maximum bloat severity". A considerable amount of severe bloat occurred from the middle of May until early August. After an initial control period for establishment of the bloating pattern, the animals were divided into three groups of approximately equal bloating potential by blocking on

TABLE 1. DATES WHEN THE VARIOUS TREATMENTS WERE STARTED[a]

Date	Group 1	Group 2	Group 3
May 16	35 P+70 E+140 S	140 S	Control
May 18	35 P+70 E+210 S	210 S	
May 23	35 P+70 E+70 NOVO	70 NOVO	
June 2		35 P	
June 13		70 P	
June 16	Control		70 P+70 E
June 20		70 E	
July 7		70 P	
July 11		70 O	35 NEO
July 14		140 O	70 NEO
July 25	70 NEO	70 P	Control
Aug. 3	70 T	70 C	
Aug. 6	105 T	140 C	
Aug. 16	70 V	70 T+70 V	
Aug. 20	140 V	70 V	
Aug. 28	Experiment terminated		

[a] E=Erythromycin, C=Chloramphenicol, NEO=Neomycin, NOVO=Novobiocin, O=Oxytetracycline, P=Procaine penicillin, S=Spontin (Ristocetin), T=Tylosin, V=Vancomycin. Levels indicated are in mg. per animal per day.

total bloat scores. Initially there were 12 unfistulated animals in each group; fistulated animals were not included in the blocking procedure, but two were allotted to each group. Some animals were removed permanently from the experiment by death or disease; some were removed temporarily because of rumenotomy or other factors. Three animals were added at appropriate times in an attempt to maintain numbers. Nevertheless, the minimum number of unfistulated animals per group declined to 10. Serious cases of bloat were treated by a method to be described in a subsequent paper.

After allocation of the animals to the three groups, antibiotics were fed to two of the groups at the levels and for the periods indicated in table 1. Antibiotics to be tested were chosen on the basis of commercial availability, activity against Gram-positive organisms and lack of cross-resistance to one another.[4] Experimental periods were not fixed, but each

[4] The antibiotics used in these studies were kindly supplied by the following: Abbott Laboratories (Spontin); Eli Lilly and Co. (erythromycin, tylosin and vancomycin); Merck Sharp and Dohme (procaine penicillin); Parke, Davis and Co. (chloramphenicol); Chas. Pfizer and Co. (oxytetracycline); Upjohn Co. (novobiocin and neomycin).

antibiotic or combination of antibiotics was fed until it was proven ineffective, or if initially effective, until serious cases of bloat occurred in that group, indicating that resistance had developed.

The degree of antibiotic resistance of the facultative anaerobic lactobacilli and streptococci was estimated by plating dilutions of rumen ingesta in APT agar (Case Laboratories) and thallous acetate agar (Hartman, 1960), respectively, containing no antibiotic, 2.0 units per ml. of penicillin, or 10.0 mcg. per ml. of erythromycin. Samples of the rumen ingesta were taken via the fistulas shortly after the morning allotment of grain. Arm length, disposable plastic gloves were worn in order to guard against possible cross-inoculation during the sampling procedures.

Results

Daily observations of incidence and severity of bloat are shown in the figures. Selected data which demonstrate the efficacy of the various antibiotic treatments are summarized in table 2. Values for only the unfistulated animals are included. The effects of feeding penicillin and erythromycin in combination are shown in figure 1 (daily average maximum bloat) and figure 2 (daily average bloat). Serious cases of bloat (a bloat score of 3 or above) were infrequent when daily average maximum bloat was less than 0.4 (figure 1) or daily average bloat severity was less than 0.2 (figure 2). Because the daily average and the daily average maximum curves were quite similar, only the former were plotted to illustrate

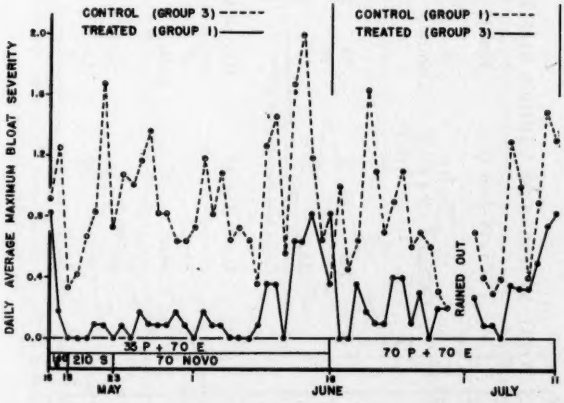

Figure 1. Effects of feeding antibiotics in combination upon average maximum bloat severity. (P=procaine penicillin, E= erythromycin, S=Spontin, NOVO=novobiocin). Levels indicated are in mg. per animal per day.

TABLE 2. TOTAL NUMBERS OF VARIOUS BLOAT SCORES OBSERVED DURING CERTAIN PERIODS OF TREATMENT

Period	May 17–June 11		June 17–July 9		June 3–June 11		June 21–July 5		Aug. 4–Aug. 14	
No. of animals	11	11	10	11	11	10	10	10	11	11
Treatment[a]	Control	P+E+S or NOVO	Control	P+E	Control	P	Control	E	Control	T
Bloat score										
1	105	22	48	39	31	17	29	32	23	16
2	52	1	19	1	18	3	7	3	13	3
3 or higher	15	1	22	2	5	0	12	0	18	3

Period	Aug. 7–Aug. 15		May 24–May 28		July 12–July 18		July 12–July 25		May 17–May 23	
No. of animals	11	12	12	11	11	12	11	11	12	11
Treatment[a]	Control	C	Control	NOVO	Control	O	Control	NEO	Control	S
Bloat score										
1	17	15	20	7	21	20	36	26	32	9
2	7	6	18	5	6	2	14	5	8	7
3 or higher	13	0	2	2	5	1	11	6	6	5

[a] P=Procaine penicillin, E=Erythromycin, S=Spontin, NOVO=Novobiocin, T=Tylosin, C=Chloramphenicol, O=Oxytetracyline, NEO=Neomycin.

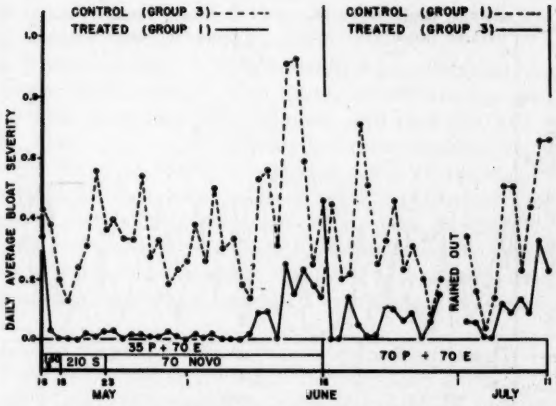

Figure 2. Effects of feeding antibiotics in combination upon average bloat severity. (P=procaine penicillin, E=erythromycin, S=Spontin, NOVO=novobiocin). Levels indicated are in mg. per animal per day.

the other results (figures 3, 4 and 5). The average values were low when compared with the scale used in evaluating bloat severity; this was due to inclusion of many zero observations during hours when very few ani-

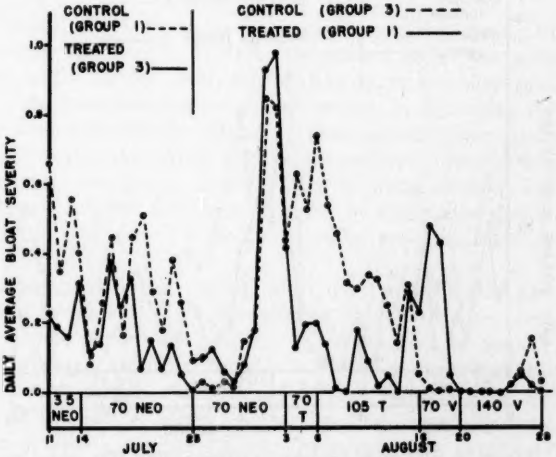

Figure 3. Effects of feeding neomycin (NEO), tylosin (T) and vancomycin (V) upon average bloat severity. Levels indicated are in mg. per animal per day.

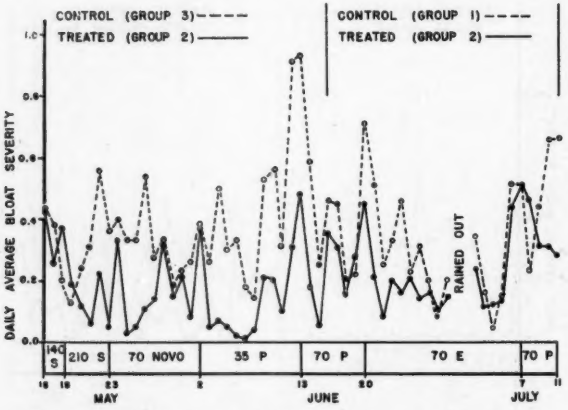

Figure 4. Effects of feeding Spontin (S), novobiocin (NOVO), procaine penicillin (P) and erythromycin (E) upon average bloat severity. Levels indicated are in mg. per animal per day.

mals bloated and from the inclusion of all animals, some of which seldom bloated. Penicillin and erythromycin fed in combination (table 2 and figures 1 and 2) controlled bloat more effectively and for a longer period

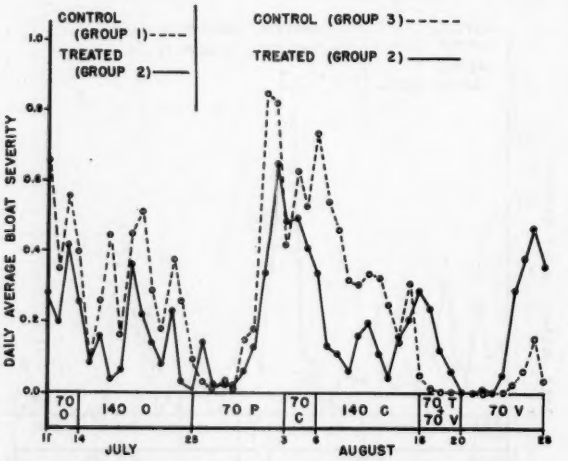

Figure 5. Effects of feeding oxytetracycline (O), procaine penicillin (P), chloramphenicol (C), tylosin (T), and vancomycin (V) upon average bloat severity. Levels indicated are in mg. per animal per day.

of time (26 days in one trial, 23 days in another) than did the same antibiotics fed in rotation (table 2 and figure 4).

Novobiocin and Spontin may have exerted an additional preventive effect, since the daily average bloat scores of the treated group were lower when these antibiotics were included with penicillin and erythromycin than when only a penicillin-erythromycin combination was fed (figures 1 and 2). This, however, was due solely to the occurrence of more cases of slight bloat (bloat score of 1) in the latter instance (table 2). Novobiocin and Spontin evidently reduced the incidence of slight bloat but were not requisite to adequate practical control of bloat. Mild bloat (score of 2) and serious bloat (score of 3 or above) were rarely observed in the animals which received a combination of penicillin and erythromycin.

With regard to duration of effectiveness when fed individually (table 2; figures 3, 4 and 5), procaine penicillin (35 mg.) and erythromycin (70 mg.) controlled bloat the longest (about 10 days); tylosin (105 mg.) was effective about as long, but bloat was declining in the control group toward the end and this may have obscured the true effect of the tylosin. Chloramphenicol (140 mg.) was effective for about 7 days during a time of less serious bloat. Novobiocin (70 mg.) was effective for approximately 4 days. Oxytetracycline (140 mg.) reduced bloat substantially for about 4 days and was less effective thereafter. Neomycin (70 mg.) seemed to reduce bloat under some circumstances, but the results were variable and difficult to interpret (figure 3). Spontin (210 mg.) may have reduced bloat somewhat.

A combination of tylosin and vancomycin was tested during the late season when the incidence of bloat in the control group was quite low. Vancomycin, at the 70 mg. level, appeared to encourage bloat symptoms (figure 3). This phenomenon was reversed, in part, by increasing the daily vancomycin dosage to 140 mg. (figure 3), or by simultaneous administration of tylosin (figure 5). When tylosin was omitted from the ration of the vancomycin-tylosin group (figure 5), the incidence of bloat increased to about three times the incidence observed in the control group. The severity of bloat also seemed to be increased by vancomycin administration.

Penicillin did not effectively control bloat when added to the diet after being withheld for periods of 17 days (figure 4) and 14 days (figure 5). Plate counts made periodically revealed the appearance of penicillin- or erythromycin-resistant strains of bacteria in the rumen ingesta of fistulated animals fed the respective antibiotics. Resistant bacteria also appeared sporadically in the control animals, indicating that there may have been a transfer of antibiotic-resistant strains from treated to control groups, possibly by mouth through the common water supply or via the forage. The resistant strains tended to persist for some time in both treated and control animals.

Discussion

Results of these trials demonstrate that serious bloat can be prevented for extended periods by feeding certain antibiotics in rotation or in combination. The feeding of antibiotics in sequence would afford protection by successive antibiotics while resistance to previously administered antibiotics might diminish sufficiently so that effectiveness could be regained for repeated usage. This arrangement would probably be satisfactory if a sufficient number of effective antibiotics were available. On the other hand, penicillin and erythromycin fed in combination controlled bloat more effectively and for a longer period of time than did the same antibiotics fed in rotation. Cost considerations suggest rotational feeding as the more practical, while the overall effectiveness and the difficulty of preparing several different feeds for bloat control, each with a single antibiotic, indicate that feeding combinations of antibiotics may be the more practical approach to bloat control. A possible disadvantage of the use of combinations of antibiotics is that the end of the effective period is marked by resistance to the pair, rather than to just a single antibiotic. Use of another combination might not afford a long enough time lapse between prior and repeated usage to allow adequate diminution of resistance to a low level. Conversely, sequential administration of four or five antibiotics could probably extend the interim for an adequate period.

Additional work is necessary to determine the appropriate levels, the best sequences and proper synergistic combinations to use. Several possibilities are suggested by the present studies; for example, a logical combination would be tylosin and chloramphenicol. Various sequences and other combinations can be postulated.

It must be recognized that the order in which the antibiotics were fed (table 1) may have influenced the response. For example, oxytetracycline followed erythromycin and penicillin, sequentially, and the effect of oxytetracycline might have been more pronounced if it had followed a control period; however, chloramphenicol was fed under somewhat similar circumstances and effected a reduction in bloat. Tylosin administration did not closely follow any effective treatment.

The problem of drug resistance and reversal will be a critical factor in rotation- or combination-prophylaxis of bloat. Barrentine *et al.* (1958) noted that resistance which developed to penicillin, erythromycin and oxytetracycline seemed to be general, rather than to a specific antibiotic. Cross resistance to different types of antibiotics is virtually unknown (Spector, 1957). The generalized resistance observed by Barrentine *et al.* (1958) can be best attributed to the selection of multiple resistant strains of microorganisms by exposure of the rumen microflora to antibiotics in fairly rapid succession, or to multiplication of one or more rarely occurring multiple resistant mutants. The present data add credence to the latter theories. In addition, demonstration that resistant forms can invade and multiply in the rumens of control animals as well as treated animals has

wider implications; control animals are not always controls in the pure sense of the term, since the rumen microflora may be indirectly affected by the diet of treatment groups.

Further studies are necessary to determine the side effects, if any, on the animals. None of the antibiotics used in the present studies appeared to have any adverse effects, with the possible exception of vancomycin which seemed to aggravate bloat. Various investigators recently have reported that effective levels of penicillin (Emery *et al.*, 1958b; Heinemann *et al.*, 1958; Johnson *et al.*, 1958a; Johns *et al.*, 1959; Mangan *et al.*, 1959), erythromycin (Johnson *et al.*, 1958b), or the tetracyclines (Heinemann *et al.*, 1958; Shor *et al.*, (1959) produced no undesirable side-effects on the animals.

In the present study, the antibiotics were administered in the grain. Alternative methods of administration might be via the salt or the drinking water. Successful use in the latter, however, must await development of water-stable forms of a sufficient number of appropriate antibiotics.

Summary

During the 1959 pasture season three groups of dairy and beef cattle, approximately equal in bloating potential, grazed bloat-provoking alfalfa pasture. Each group received several antibiotics in combination or in rotation or served as control. Results indicated that the period of effectiveness of antibiotics can be extended considerably by feeding several different antibiotics in rotation or by feeding them in combinations. Those found particularly effective were penicillin, erythromycin and tylosin; chloramphenicol, novobiocin and oxytetracycline were less effective. Neomycin and Spontin were of questionable value. Limited data indicated that vancomycin may, under some conditions, increase bloat. Penicillin and erythromycin were more effective for a longer period of time when fed together than when fed in rotation.

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OBSERVATIONS ON THE EFFECT OF DRYING ON ESTROGENIC ACTIVITY OF ALFALFA SAMPLES OF VARYING MATURITY

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RECENT work has shown that beef cattle are less responsive to the growth-promoting effects of diethylstilbestrol when the basal diet contains estrogen-rich dehydrated alfalfa meal (Matsushima, 1959). This work suggests that an estrogenically active alfalfa meal may have a definite value in livestock production. However, commercially dehydrated meals as now produced are extremely variable, some being completely devoid of activity (Bickoff *et al.*, 1959). This makes it difficult to evaluate the significance of the plant estrogens in livestock production until more information is available on the factors affecting estrogen levels in commercially dehydrated meals. Kitts *et al.* (1959) have recently offered at least five possible explanations for these large variations. Their findings, as well as the earlier studies of Pieterse and Andrews (1956), indicate that stage of maturity of the alfalfa at the time of harvest is one of the most important factors influencing estrogenic content.

The primary objective is to determine the effect of artificial drying on the estrogenic activity of our material since earlier work had suggested that some activity may be lost during the drying process (Bickoff *et al.*, 1959, 1960). The second objective of this report is to present additional information regarding the amount of estrogen in alfalfa as related to the growth stage of the alfalfa at the time of cutting.

Materials and Methods

Plant Material. Alfalfa (Medicago sativa, var. Chilean) was seeded in 1956 at Albany, California in a plot, 30 ft. x 100 ft., adjacent to the laboratory. The alfalfa was planted in 30-ft. rows about 2 feet apart. For this study, sufficient top soil was brought in to prepare a plant bed about 2 feet deep, resulting in uniform soil conditions within the plot. The plot was irrigated, cultivated, and fertilized with considerable care, resulting in quite uniform growth throughout and at the time of samplings the entire plot showed a uniform stage of development. Sampling was done by selecting consecutive marginal rows and an entire row was harvested for each sample studied, the plants being cut about 2 inches from the ground.

Samples for this study were harvested during the 1958 and 1959 grow-

[1] The authors wish to thank Mrs. Ann R. Gramps for the preparation of many of the samples for analysis.

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ing seasons. In 1958, five cuttings were made; in 1959, only the first spring growth was studied. During each growth period between cuttings, a series of 8 to 12 successive samples was taken. The terms, 1/4 bloom, 1/10 bloom, etc., indicate that approximately 1/4 or 1/10 of all potential blossoms on all the stems from a single crown had opened at the time the sample was taken from the ground.

Methods of Assay. In most procedures for the estrogenic evaluation of forages, the fresh sample is oven-dried, ground, and then extracted with a solvent such as alcohol or acetone. Since the drying operation may cause loss of estrogen activity (Bickoff *et al.*, 1959, 1960), an assay which does not require preliminary drying of the alfalfa was used, in addition to the customary method. The freshly harvested plant tissue was treated directly with acetone in a mechanical disintegrator and the resulting extract, after further purification, was added to the mouse diet and the solvent evaporated. Details of procedures for preparation of extracts from fresh and dried tissues, as well as the techniques for determination of the level of estrogenic activity in these extracts have been described (Bickoff *et al.*, 1959).

Since coumestrol appears to be the predominant estrogen in alfalfa, the estrogenic activity can be conveniently reported in terms of coumestrol equivalence. However, the bioassay for estrogenic activity may be influenced by estrogen inhibitors or potentiators which are known to be present in alfalfa (Bickoff *et al.*, 1960), perhaps in various relative proportions in different samples. For this reason, the biologically measured total activity is expressed as "apparent coumestrol". The calibration curve employed to convert average uterine weight response to coumestrol equivalence has been published (Bickoff, 1959).

In order to determine the nature of the response to various levels of extracts, dilution assays were conducted with both freshly harvested and oven-dried samples. An extract prepared from a highly active sample of freshly harvested alfalfa was added to the feed mixture to give the equivalent of 3 gm. of alfalfa per 10 gm. of mouse ration. From this alfalfa extract-feed mixture, a number of dilutions were prepared by admixture with additional quantities of basal mouse ration. Each of these preparations was then assayed for activity. Mice, caged in groups of five were allowed to eat *ad lib.* until an average of 10 gm. of diet was consumed by each mouse. The relationship between uterine response and quantity of extract fed closely paralleled that for pure coumestrol, with the result that the "apparent coumestrol" in mg./kg. of alfalfa was approximately the same for all levels fed (table 1). Similar results were obtained with the oven-dried samples.

Most samples were initially assayed at a level equivalent to 8 gm. of alfalfa per 10 gm. of mouse diet. For the best quantitation suitable dilutions of our test extracts were made so that the average uterine weights at the conclusion of the tests did not exceed 35 mg. Equivalent weights

TABLE 1. RESPONSE OF IMMATURE FEMALE MICE TO GRADED LEVELS OF ALFALFA

Diet			"Apparent coumestrol"	
Alfalfa equivalence, (gm./10 gm. ration)	Number of mice	Average uterine response, mg.	Micrograms per mouse	mg./kg. of alfalfa
1.5	15	18.5	200	133
2.0	14	22.5	266	133
2.5	10	27.2	320	128
3.0	15	36.7	417	139

of alfalfa fed ranged from 1 to 8 gm. per mouse. In most cases, the results presented are the average of several bioassays for each sample, each individual assay being carried out with five mice in a single cage. Since the technique for assay of fresh samples had not been developed at the time the present study was begun, the assays of the first growth in the 1958 season are on oven-dried samples only. For most samples of subsequent cuttings, comparable assays of both fresh and dried material are presented.

Results and Discussion

Stage of Growth. Variation in estrogenic activity with stage of growth is shown in tables 2 to 7. In the spring growth (first crop) there was a slight amount of activity in the vegetative stage followed by a decline to zero until 1/10 bloom, then the activity increased progressively during bloom, reaching a maximum at the dough stage of the seed and remaining at this high level through the mature seedhead stage.

It is interesting to compare these results with those of Pieterse and

TABLE 2. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(First Growth—Begun March 5, 1958)

Stage of maturity	Height of stand, (inches)	Apparent coumestrol, (mg./kg. of alfalfa)
Vegetative	3–6	4
Vegetative	4–8	13
Vegetative	8–14	9
Early bud	10–16	0
Bud	12–20	0
Full bud	16–24	0
Prebloom	20–28	0
1/10 bloom	22–28	7
1/4 bloom	24–30	9
1/2 bloom	24–36	33
Full bloom	24–36	77
Dough	24–36	120
Seedhead	24–36	123

TABLE 3. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(Second Growth—Begun May 19, 1958)

Stage of maturity	Height of stand (inches)	Apparent coumestrol	
		Dried sample (mg./kg. of alfalfa)	Fresh sample (mg./kg., dry basis)
Vegetative	4–10	1	0
Early bud	16–20	6	0
Full bud	18–22	8	0
1/10 bloom	20–24	5	0
1/4 bloom	24–30	14	20
1/2 bloom	24–36	60	63
Full bloom	24–36	184	262
Dough	24–36	82	94
Seedhead	24–36	110	187

Andrews (1956). The results of their assay of first spring growth agree with ours in exhibiting very slight activity until 1/10 bloom, with the exception of a sudden, short-lived appearance of activity during the early budding stage. They, too, found a steady, progressive increase in activity during the blossoming period; activity reached a maximum at about full bloom and remained high through the dough and seedhead stages. The highest values that they reported for spring growth were only about one-third of the maximum values found in our comparable samples of first growth in the 1958 season.

In our studies, the second growth of the 1958 season (table 3) was quite similar to that of the first growth. The Purdue workers reported that their second crop showed activity only in the dough stage (Pieterse and Andrews, 1956).

The third cutting (table 4) differed considerably from that of the

TABLE 4. ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(Third Growth—Begun July 7, 1958)

Stage of maturity	Height of stand (inches)	Apparent coumestrol	
		Dried sample (mg./kg.)	Fresh sample (mg./kg., dry basis)
Vegetative	18–24	6	6
Bud	20–30	108	111
1/10 bloom	24–36	89	92
1/2 bloom	30–40	142	93
Full bloom	40–48	92	98
Dough	40–48	128	181
Seedhead	40–48	120	210

TABLE 5. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(Fourth Growth—Begun August 18, 1958)

Stage of maturity	Height of stand (inches)	Apparent coumestrol	
		Dried sample (mg./kg.)	Fresh sample (mg./kg., dry basis)
Vegetative	8–12	5	11
Vegetative	16–20	5	1
Full bud	16–22	1	1
1/10 bloom	18–24	5	49
1/4 bloom	18–25	34	47
1/2 bloom	18–26	32	43
Full bloom	18–26	57	103
Dough	20–26	91	93
Seedhead	20–26	155	198

first and second. The estrogenic activity, which was quite low during the vegetative stage, increased rapidly to a very high level during the early bud stage and remained at a consistently high level throughout the entire life cycle of this growth.

The fourth growth (table 5) again reverted to the pattern of the first and second cuttings in showing little activity until 1/10 bloom and then increasing progressively to its maximum level at the full bloom and dough stages.

Since it is possible for alfalfa to overwinter and to maintain some growth in the relatively mild winters of Albany, California, a fifth growth started on October 8. This crop grew throughout the winter but remained vegetative and never bloomed. The estrogen activity (table 6) suddenly became very high after about 2 months of plant growth, at which time the plant was still in a full-bud stage. This study was discontinued after

TABLE 6. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(Fifth Growth—Begun October 8, 1958)

Stage of maturity	Height of stand (inches)	Apparent coumestrol	
		Dried sample (mg./kg.)	Fresh sample (mg./kg., dry basis)
Vegetative	4–8	7	7
Early bud	6–16	8	20
Full bud	15–20	24	17
Dormant-prebloom	15–20	14	116
Dormant-prebloom	15–20	80	147

3 months of slow growth at which time the estrogen content was still high. The results of the third and fifth growths demonstrate that it is not essential for the plant to bloom in order for the estrogen content to reach and maintain high levels.

The first crop of the 1959 season (table 7) showed some activity at the early vegetative stage, gradually building up to a maximum value at ¼ bloom, then decreasing until full bloom when it rapidly increased again to a level higher than that attained at 1/10 bloom. The highest values reached during this growth were only about one-third of those attained during the comparable stages of growth of the 1958 crop.

TABLE 7. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(First Growth—Begun March 5, 1959)

Stage of maturity	Height of stand (inches)	Apparent coumestrol	
		Dried sample (mg./kg.)	Fresh sample (mg./kg., dry basis)
Vegetative	6–14	3	12
Vegetative	12–18	4	13
Early bud	16–24	6	11
Bud	16–24	6	12
Full bud	18–34	10	10
1/10 bloom	20–42	17	23
1/4 bloom	20–45	14	27
1/3 bloom	24–60	24	25
1/2 bloom	24–60	18	17
3/4 bloom	24–60	16	18
Full bloom	24–60	16	44
Dough stage	24–60	21	41

With the exception of the first growth in 1958, our results differ considerably from those of Pieterse and Andrews (1956) since we find high estrogen activity in some stages of each of the five cuttings studied during the 1958 season; whereas, Pieterse and Andrews reported that their third and fourth crops showed almost no activity throughout the entire growing period.

Kitts *et al.* (1959) have recently completed a similar study with alfalfa grown in British Columbia. They reported that the estrogenic content was highest at the vegetative stage, tended to decrease until full bloom, and then increased again in late bloom when the plants were partially in the dough stage. They concluded that estrogenic activity was not associated solely with the phase of rapid growth nor with the reproductive phase of the plant. Four successive cuttings of alfalfa were made throughout the summer, all plants being harvested at almost the same stage of develop-

ment. The estrogenic content was high in the spring, tended to decrease during the summer but build up again in the fall. In contrast, our work revealed high estrogen levels in all summer cuttings; and, the Purdue group found that alfalfa cuttings subsequent to the first tend to be lower in estrogenic activity. It should be pointed out that these apparently divergent results, obtained at stations widely separated from one another geographically, may result from differences in climate, soil conditions, fertilizers, variety of alfalfa or other factors. The very mild climate of Albany, California, is certainly not typical of most of the areas in which alfalfa is commercially grown.

It would appear desirable to investigate further the variables that need to be controlled in order to produce a consistently high-estrogen alfalfa meal. Possibly, by plant selection, alfalfas with more estrogen or other growth-promoting factors could be produced.

Effect of Dehydration on Estrogen Content. Since alfalfa is preserved for winter feeding either by sun-curing or dehydration, it is of considerable interest to determine whether the drying process alters estrogenic activity. Furthermore, farm animals might be exposed to a more potent estrogen from fresh forage than uterine weight assays of mice would indicate, (Pieterse and Andrews 1956), if assays are based only on dried samples, as has been the case with most of the reported studies.

Biggers (1959) reports that dehydration does cause a loss of estrogen activity. Alexander and Watson (1951) examined the effects of several methods of drying and reported that dehydration of Subterranean clover is accompanied by a loss of activity. It has also been reported that haymaking may reduce estrogenic activity (von Erkelens and von der Veen, 1958). In this connection, Siddiqui (1945) noted that drying of chana grain at room temperature resulted in a loss of the estrogenic isoflavone, biochanin A.

Since comparative assays of fresh and dried forage have shown that the apparent estrogenic activity was sometimes lower in the dried samples (Bickoff, 1959), the present study was designed to clarify this point. Samples were assayed first as fresh forage and again after drying. Some of the samples lost no estrogenic activity on drying, whereas others suffered a loss of as much as three-fourths or more of their original estrogenic activity (tables 3 to 7). The reasons for these differences are not immediately apparent. Drying time ranged from 45 minutes to 2 hours at 70° C., depending on the maturity and moisture content of the sample. Pieterse and Andrews (1956) suggested a 24- to 48-hour drying time at a temperature of 170° F. (77° C.) We found little if any additional loss after 24 hours as compared to 1 hour. Part of the apparent estrogenic loss on drying may be attributable to varying degrees of destruction or inactivation of an estrogen potentiator; this must await further work on characterization of these unknown factors. A chemical assay for plant estrogens is strongly suggested for further studies of this nature, to supplement the

bioassay method. Such a chemical method for the estrogen, coumestrol, is now under development in our laboratories. Meanwhile, we recommend that the preliminary drying operation be eliminated in the bioassay of fresh forage for estrogenic activity.

Summary

The estrogenic activity of alfalfa was compared at different stages of maturity in five crops cut during 1958 and in the spring growth (first crop) of the 1959 season. Estrogen content followed a fairly similar pattern in all of the crops. The estrogen content was quite low in the vegetative stages and then increased gradually as the plant matured, usually reaching its highest level at about the full bloom or seedhead stages. The third crop attained its peak activity in the early bud stage and remained high throughout the life cycle of the plant. The winter growth attained high levels of activity without ever blossoming. The 1959 crop never attained more than one-third of the peak activity of the comparable 1958 crop.

Drying fresh forage samples prior to assay sometimes leads to significant losses of apparent estrogen activity. The amount of loss varied considerably in different samples, ranging from no loss in some cases, to more than 75% in others. It is recommended that fresh forage samples be assayed without prior drying.

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AVAILABILITY OF COPPER TO SHEEP FROM Cu-64 LABELED INORGANIC COMPOUNDS [1]

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NATURALLY occurring copper deficiency of cattle and sheep has been reported in Australia, New Zealand, South Africa, Scotland and the United States. An excellent review of these area problems has been presented by McElroy and Glass (1950). Literature on the role of copper in animal nutrition was thoroughly reviewed by Underwood (1956) and copper nutrition in ruminants was discussed in Nutrition Reviews (1958).

Copper supplementation is better to the animal than through soil fertilization according to Davis (1957). However, little is known of the relative availability of copper from different copper compounds to animals. Several Workers (Yoshikawa *et al.*, 1942; Comar, 1950; Schubert, 1948) have used radioactive copper-64 in the nitrate or sulfate form to determine absorption, tissue distribution and excretion pathway for this element.

The purpose of this investigation with sheep was to determine the relative availability of copper-64 from cupric sulfate, cupric chloride, cupric oxide needles and powder, cuprous oxide, cupric nitrate, cupric carbonate and copper wire.

Experimental Procedure

Three experiments were conducted with mature wethers of similar origin, weight and breed. The same 16 sheep were used in experiments 1 and 2 but a different group of 14 were used in the third experiment. Metabolism crates as described by Hansard *et al.* (1951) were used for accurate collection of feces and urine. During the preliminary phase and throughout the experimental period each animal was fed daily a complete mixed ration composed of 62% cottonseed hulls, 23% corn, 9% soybean oil meal, 5% alfalfa meal, 0.94% salt, 0.06% dicalcium phosphate and vitamin D_2.

Copper-64 labeled materials administered in these experiments were obtained by thermal neutron activation of stable copper compounds in the graphite reactor at Oak Ridge National Laboratory. A quantity of the

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desired compound sufficient for a single animal was weighed into a gelatin capsule, and all capsules containing this compound for a single trial were enclosed in a larger capsule in order to achieve approximately constant specific activity. Calcium chloride was placed in the larger capsule when necessary to maintain anhydrous condition for hygroscopic salts. Following activation, the small capsules were removed from the larger one, and either administered directly to the animals orally, or dissolved in distilled water in a single container from which aliquots were drawn for intravenous injection through a catheter into the left jugular vein.

TABLE 1. SOURCE AND METHOD OF ADMINISTRATION OF COPPER TO SHEEP

Source	Mg. of copper	Mc. of Cu-64	Method of administration	No. of sheep
Experiment 1				
Cupric sulfate	20	5	Oral	4
Cupric chloride	20	5	Oral	4
Cupric oxide needles *	20	5	Oral	4
Cupric nitrate	20	5	Oral	4
Experiment 2				
Cupric sulfate	15	3	I.V.	4
Cupric chloride	15	3	I.V.	4
Cupric nitrate	15	3	I.V.	4
Copper wire	5000	14	Oral	4
Experiment 3				
Cupric oxide powder	20	5	Oral	4
Cupric oxide needles *	20	5	Oral	3
Cuprous oxide powder	20	5	Oral	3
Cupric Carbonate	20	5	Oral	4

* Needles, 26 gauge "stubs", 1–4 mm. in length.

Reference solutions for relative counting were prepared by diluting aliquots of the solutions for intravenous administration, or by dissolving capsules containing equal weights of compounds administered orally. Equal volumes of reference solution, blood, plasma, urine, and feces were counted for Cu-64 activity in well-type scintillation counters. Approximately 3 gm. of feces were weighed and compacted into the required counting volume for correct geometry. Blood samples were withdrawn from the animals from the right jugular vein with heparinized syringes and then standard volumes were taken for counting.

Each experiment was terminated after 96 hours because of the short half-life of Cu-64, and the presence of longer-lived radioactive contaminants which have been shown to interfere (Frierson *et al.*, 1952).

In experiment 1, sixteen mature wethers were divided into four comparable groups of four each and were orally given 20 mg. equivalent copper with an activity of 5 mc. The following compounds (table 1) were tested:

Cupric sulfate, cupric chloride, cupric oxide needles and cupric nitrate. Urinary, fecal and blood collections were taken from each animal at 4-hour intervals for the first 24 hours, then at 24-hour intervals through 96 hours after administering the isotope.

In experiment 2, seven days after the dosing in experiment 1, the same groups of sheep were randomly reallotted for the new treatments. Three groups were given 3 mc. of copper-64 intravenously as cupric sulfate, cupric chloride or cupric nitrate. The remaining four animals were given orally 14 mc. of copper-64 in a 5.0 gm. bundle of reagent grade No. 24 copper metal wire. At the completion of the 96-hour isotope phase, the four sheep receiving the wire bundles and one control animal were sacrificed to recover the wire bundles and to check for tissue damage.

In experiment 3, fourteen additional wethers were used in testing orally administered cupric oxide powder, cupric oxide needles, cuprous oxide powder and cupric carbonate. The number of sheep receiving each compound was 4, 3, 3, and 4, respectively.

Results

Data obtained from each of the three experiments have been summarized in figures 1, 2 and 3 and table 2. Figures 1, 2 and 3 show the concentration of copper-64 in the blood, plasma, feces and urine of sheep on the various treatments. The multiple range test for copper concentrations from the different forms is summarized for each experiment in table 2.

In experiment 1, the blood and plasma concentrations from oral dosing with the sulfate, chloride and nitrate forms ranged between 0.1% and 0.4% of dose per liter, but only 0.04% of dose per liter resulted from administration of cupric oxide needles. Cumulative fecal excretions averaged from 78% to 87% of the dose in 96 hours for the sulfate, chloride and nitrate but only 3% of the dose for the cupric oxide needles. The activity from the oxide form was lower ($P<0.01$) in blood, plasma, feces and urine than from any other source tested. Although the sulfate, chloride and nitrate reacted similarly, significantly greater ($P<0.05$) blood and plasma concentrations were found from the chlorides.

Intravenous injections of cupric sulfate, nitrate and chloride in experiment 2 showed that the cumulative excretion of the chloride in the urine was greater ($P<0.01$) than from the sulfate or nitrate forms. The percent of the dose observed from the copper wire bundles was less than 0.1% excreted and generally neither blood nor plasma contained as much as 0.005% dose per liter. When each animal was sacrificed, the wire bundle was recovered from the same location in the reticula.

Of the copper compounds tested in experiment 3 the carbonate resulted in the highest ($P<0.01$) blood and plasma concentration. The cupric oxide powder resulted in greater ($P<0.01$) blood and plasma concentration than the cupric oxide needles or cuprous oxide. Cumulative fecal

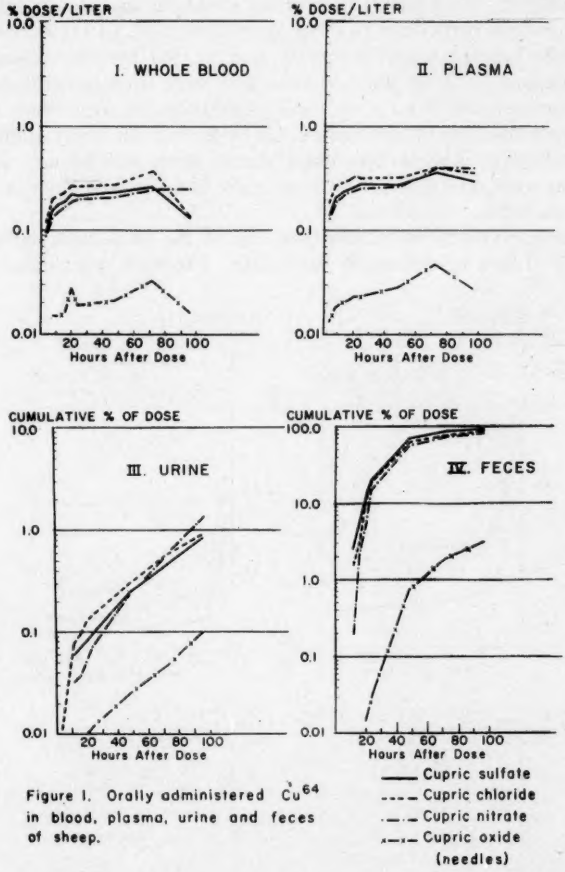

Figure 1. Orally administered Cu^{64} in blood, plasma, urine and feces of sheep.

excretions averaged 7%, 80% and 94%, respectively, for the cupric oxide needles, cupric carbonate and cuprous oxide powder.

The greatest ($P<0.01$) cumulative urine excretion was 3.1% of dose from the cupric carbonate treatment, whereas it was only 0.19% to 0.23% from the other treatments.

Discussion. These data indicate that the chemical and physical forms of copper affect its availability to sheep. In a comparison of the more soluble forms, the chloride promoted higher blood and plasma activity of copper than the sulfate or nitrate in both orally and intravenous administered doses.

Significantly more Cu-64 was excreted in urine from intravenous admin-

istered chloride. The chloride form is not as soluble in water as the nitrate form; therefore, there must be other factors involved. Of these three forms the sulfate has the lowest solubility and on the average exhibited the lowest amount in blood, plasma, urine and feces from intravenous doses. These results are indicative of tissue preference for the sulfate form of copper over the chloride and nitrate. Cu-64 levels from orally administered cupric carbonate in whole blood and plasma along with urinary and fecal excretions were similar to levels from orally administered chloride, sulfate and nitrate forms.

In the intravenous study less than 3% of the total dose was excreted within 96 hours regardless of the source. Excretion was about equally

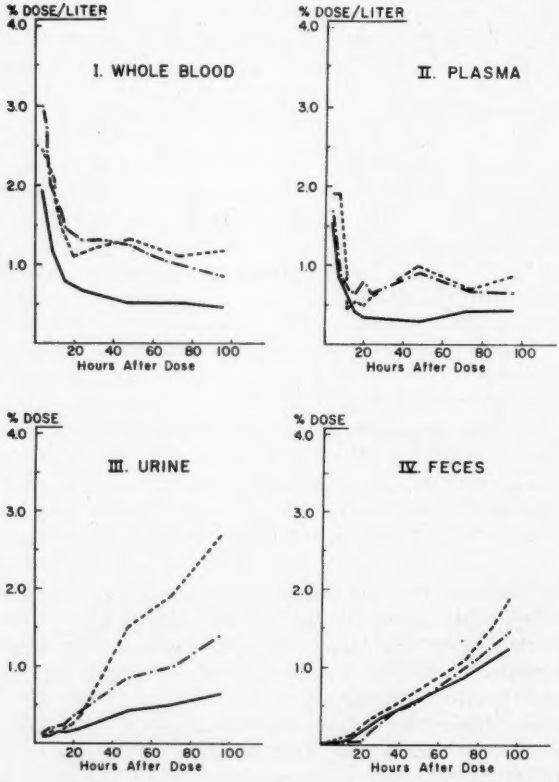

Figure 2 Intravenously administered Cu^{64} in blood, plasma, urine and feces of sheep.

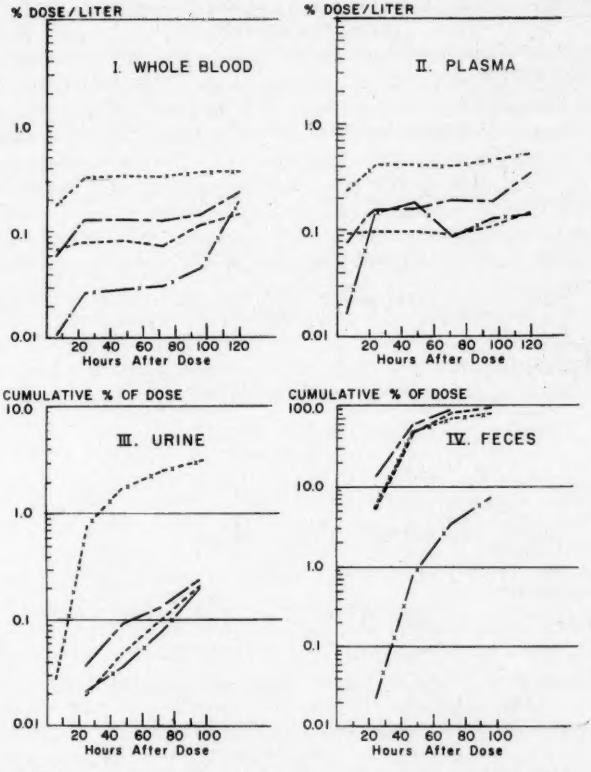

Figure 3. Cu^{64} in blood, plasma, urine and feces of sheep from orally administered oxides and carbonate.

divided between urine and feces. It was of interest to note that the urinary excretion from the chloride form was significantly greater ($P<0.05$) than from the nitrate and sulfate forms. Fecal differences were not significantly different although they showed the same trend as in the urine. These results agree closely with those of Comar (1950) who found only 6% of the dose was excreted by cattle in 5 days, this excretion being about equally distributed between urine and feces.

Cu-64 from oxides was less available than from the more soluble forms. Cu-64 was more available from the powdered oxides than from the needles. Higher blood, plasma, urine and fecal levels were observed from cupric oxide than from cuprous oxide. Figures 1 and 3 show that copper from

TABLE 2. MULTIPLE RANGE TEST FOR COPPER CONCENTRATIONS FROM DIFFERENT SOURCES

Measurements	Sources[a]
Experiment 1	
Blood	CuO (needles) $Cu(NO_3)_2$ $CuSO_4$ $CuCl_2$
Plasma	CuO (needles) $CuSO_4$ $Cu(NO_3)_2$ $CuCl_2$
Urine	CuO (needles) $CuSO_4$ $CuCl_2$ $Cu(NO_3)_2$
Feces	CuO (needles) $Cu(NO_3)_2$ $CuCl_2$ $CuSO_4$
Experiment 2	
Blood	$CuSO_4$ $CuCl_2$ $Cu(NO_3)_2$
Plasma	$Cu(NO_3)_2$ $CuSO_4$ $CuCl_2$
Urine	$CuSO_4$ $Cu(NO_3)_2$ $CuCl_2$
Feces	$Cu(NO_3)_2$ $CuSO_4$ $CuCl_2$
Experiment 3	
Blood	CuO (needles) Cu_2O CuO (powder) $CuCO_3$
Plasma	CuO (needles) Cu_2O CuO (powder) $CuCO_3$
Urine	CuO (needles) Cu_2O CuO (powder) $CuCO_3$
Feces	CuO (needles) $CuCO_3$ Cu_2O CuO (powder)

[a] The means of any sources not underscored by the same dotted line are significantly different ($P<0.05$). Any sources not underscored by the same solid line are significantly different ($P<0.01$). Any two sources underscored by the same line are not significantly different.

the oxide needles was low in the blood, and this could not be accounted for by fecal or urinary excretion of Cu-64. The low fecal excretion from the oxide indicates that most of the needles remained in the gastrointestinal tract and may be slowly available over a long period of time. The half life of Cu-64 is too short to measure the long term availability of copper from the cupric oxide needles. Cu-64 from labeled copper wire was not available in significant quantities. The wires recovered from the sacrificed wethers showed evidence of oxidation which would be only slightly available if the oxides were removed from the wire. Dewey *et al.*

(1958) used a method similar to this to furnish cobalt to sheep from cobalt pellets.

In comparing these results with findings in other species, Schultze *et al.* (1936) found inorganic compounds such as the oxide, hydroxide, iodide and pyrophosphate as well as some organic sources to be readily utilized by anemic rats, but found that copper in the sulfide or porphyrin form was not utilized. Mills (1954) obtained evidence that a stable, water-soluble copper complex present in herbage was more readily utilized by the copper deficient rat than was inorganic copper. Mills (1958) also found that rumen microorganisms take up considerable quantities of cupric ions and form principally a water-soluble complex. If this complex form is one of the necessary steps in making copper available to ruminants, then much more research is needed to determine the availability of copper from different sources to microorganisms.

The results of these investigations show that copper availability to sheep is influenced by chemical and physical form and perhaps by other factors.

Summary

Blood and plasma concentrations after oral administration were greater ($P<0.05$) from the chloride source than from the sulfate, nitrate or cupric oxide needles sources of Cu-64. Cumulative fecal or urinary excretions from the chloride, nitrate or sulfate forms did not differ but exceeded ($P<0.01$) excretions from the cupric oxide needles.

In a subsequent experiment, the blood and plasma concentrations were significantly greater from the oral carbonate source than from the oxide sources. Cumulative fecal excretion from the cupric oxide powder was significantly greater than from the cupric carbonate, while cumulative urine excretion from the cupric carbonate was significantly greater than from the other sources.

Intravenous injection of radioactive copper-64 in the form of the chloride, nitrate or sulfate showed cumulative excretion in the urine to be greater ($P<0.01$) from the chloride source than from the nitrate or sulfate.

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PREPARATION AND BIOLOGICAL TESTING OF A PARENTERAL IRON PREPARATION [1]

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THE rapid growth of the newborn pig places an unusually high demand on dietary requirements. Frequently the most pronounced deficiency is that of iron, and supplying sufficient iron to prevent or alleviate the anemia associated with iron deficiency has presented a formidable problem. Many methods of therapy have been employed, such as regular dosing with concentrated iron solutions, oral iron tablets, and swabbing of the sow's teats with a concentrated iron-copper solution or paste. McDonald *et al.* (1955) cites London and Twigg as successfully producing an iron-dextran complex suitable for intramuscular injection and effective in treating pig anemia.

Parenteral administration of iron is a method of choice, since the intestinal absorption of iron is variable. However, several problems must be overcome before an iron preparation may be considered suitable for intramuscular use. It must contain sufficient iron to be therapeutically useful; the iron must be available for hemoglobin synthesis, and sufficiently stable not to precipitate as ferric hydroxide in contact with tissue, since ferric hydroxide will induce tissue damage often resulting in abscess formation.

The purpose of this paper is to present the preparation and biological testing data of a new parenteral iron preparation useful in treating the anemia due to iron deficiency in the newborn suckling pig.

Materials and Methods

Preparation of Dextrin-Ferric Oxide Complex. One hundred grams of ferric chloride was dissolved in 1000 ml. of distilled water. The weak ion exchange resin IR-45 (OH^-) was added in small portions to the solution at 20–25° C., waiting until the pH equilibrated before making further additions. At pH 2.8 the resin was filtered from the dark reddish-brown solution which had a volume of 750 ml. The iron and chloride (Swift, 1959) were found to be 11.0 mg./ml. and 0.47 mg./ml., respectively.

Six hundred fifty grams of dextrin were dissolved in the solution which was then heated to 115° C. for 10 minutes. The solution of stabilized sol was adjusted to pH 7.0 with sodium hydroxide and concentrated to about 150 ml. at reduced pressure. An aqueous phenol solution (75 mg./ml.) was added (10.8 ml.) and the final volume of the solution was made up

[1] Pigdex is the trademark of the American Cyanamid Company for the iron preparation.

to 165 ml. with water to make 50 mg. iron per ml. The sol was vialed and autoclaved for 20 minutes at 15 psi in preparation of biological testing.

Biological Testing. Hampshire, Yorkshire and cross-bred sows were used. All sows and litters, regardless of locations, were housed in concrete quarters and hand-fed twice daily; therefore, the suckling pigs had no access to major sources of extraneous iron.

Pigs within litters, based on pre-injection body weight were injected at two to four days of age with 2 ml. of the dextrin-ferric oxide complex or 2 ml. of Armidexan.[2] Each 2 ml. dose contained the equivalent of 100 mg. of elemental iron. All injections were administered by deep penetration of the ham muscle on the lateral aspect. Control animals were untreated. Weights and hemoglobin values were obtained immediately before treatment and at 1, 2, and 3-week intervals thereafter. In one experiment one

TABLE 1. TOXICITY OF A DEXTRIN-FERRIC OXIDE COMPLEX IN RATS[a]

Group no.	No. animals	Dose, mg. Fe/kg. body weight	Route	Remarks
1	10	200	I.P.	No deaths
2	4	300	I.P.	No deaths
3	10	400	I.P.	No deaths
4	10	600	I.P.	1 death at 48 hrs.
5	6	800	I.P.	No deaths
6	6	200	S.Q.	No deaths
7	6	400	S.Q.	No deaths
8	6	600	S.Q.	No deaths
9	6	800	S.Q.	1 death at 10 days

[a] Experiment terminated 21 days after injections.

group of treated pigs received a supplemental 2 ml. injection of the dextrin-ferric oxide complex immediately following the 2-week sampling.

Blood samples were taken from the ear vein of the pigs on test. A 0.02 ml. portion of blood was drawn into a standard Sahli pipette and discharged into a tube containing 5 ml. distilled water. One drop of concentrated ammonium hydroxide was added and mixed. The sample was shaken and allowed to stand 10 minutes for equilibration. The optical densities of all samples were read at 545 millimicrons wave length against distilled water and ammonium hydroxide blanks (Sunderman, 1953). The final values were expressed as grams per cent hemoglobin.

A major problem that may be encountered with an injectable iron preparation is toxicity. Normal male rats weighing 200–250 gm. were injected by intraperitoneal or subcutaneous routes with varying amounts of the dextrin-ferric oxide complex. The dose range was 200–800 mg. of elemental iron per kilogram body weight. The data (table 1) indicate a remarkable lack of toxicity. One rat died within 48 hours after receiving

[2] Armidexan is the trademark of the Armour Laboratories iron-dextran complex.

600 mg. Fe/kg. of body weight by intraperitoneal injection; however, no rats died in the 800-mg. group. One rat died after 10 days in the 800-mg. group injected subcutaneously. This death apparently was not due to the acute toxicity of the compound, since acute iron toxicity is usually interpreted as an overloading of the plasma iron binding capacity, resulting in death within several hours.

Varying doses of the dextrin-ferric oxide complex were injected into the ear vein of rabbits (table 2). No obvious effects were observed over a 10-day period at dose levels of 25, 50 and 100 mg. of iron per kilogram of body weight. Darkening of the ears was noted due to the sol, but disappeared within 24 hours.

TABLE 2. INTRAVENOUS TOXICITY OF A DEXTRIN-OXIDE COMPLEX IN RABBITS [a]

No. rabbits	Dose, mg. Fe/kg. body weight	Mortality
3	25	None
6	50	None
6	100	None

[a] Experiment terminated after 10 days.

Results

Field Trials. The effect of administering the dextrin-ferric oxide complex on hemoglobin regeneration and body weight is presented in table 3. Hemoglobin levels were increased within one week following iron administration. This increase persisted throughout the 3-week test period. In one experiment No. 2, table 4, although there was a suggested increase in hemoglobin, the difference was not statistically significant at 1 week after injection. With one exception, significant increases in growth were observed following iron administration.

A supplementary 2-ml. injection at 14 days of age (table 5) significantly increased the hemoglobin level at 3 and 4 weeks over the group that received the single dose. Body weights were not statistically different in the doubly-injected group.

Discussion

The use of ferric oxide sols complexed with various materials as a form of iron parenteral administration has received much attention (Nissin, 1949; Wallerstein, 1958). Many of these sols were formed by direct titration of ferric chloride with a suitable alkali followed by a step to free the sol of evolved high salt concentration. In this reported work, the use of an ion exchange resin to prepare the sol had the advantage of producing a sol free of contaminating salts, so that a desalting step was necessarily eliminated. It was determined that between pH 2.5 and 3.5

TABLE 3. TREATMENT OF PIGLET ANEMIA WITH A DEXTRIN-FERRIC OXIDE COMPLEX[a]

Exp. no.	Treatment	No. pigs	Mortality	Hemoglobin (gm. %)				Weight (lb.)			
				0	1 wk.	2 wk.	3 wk.	0	1 wk.	2 wk.	3 wk.
1	Control	23	1	9.7	7.2	7.7	8.1	3.5	6.5	9.8	13.0
	2 ml. Armidexan	23	0	9.8	11.3*	11.6*	10.8*	3.5	6.4	9.8	13.0
	2 ml. dextrin-ferric oxide complex	23	0	9.4	11.0*	11.6*	10.9*	3.4	6.3	9.4	12.7
2	Control	34	3	10.6	8.7	7.8	7.7	3.7	6.8	9.6	12.1
	2 ml. Armidexan	34	15	10.9	11.5*	11.4*	11.9*	3.7	6.9	10.4	13.6*
	2 ml. dextrin-ferric oxide complex	34	6	10.8	10.6*	11.0*	10.3*	3.7	7.1	10.2	13.3*
3	Control	25	4	10.9	7.8	6.8	7.5	3.7	6.1	7.9	10.2
	2 ml. Armidexan	25	2	11.2	11.8	13.1*	12.2*	3.8	6.5	9.0	11.7*
	2 ml. dextrin-ferric oxide complex	25	3	10.7	11.3*	11.1*	11.1*	3.6	6.7	8.9	11.2*

[a] Experiments conducted on various farms in Iowa.
* Statistically significant at least 5% level.

TABLE 4. TREATMENT OF PIGLET ANEMIA WITH A DEXTRIN-FERRIC OXIDE COMPLEX [a]

Exp. no.	Treatment	No. pigs	Mortality	Hemoglobin (gm. %) 0	1 wk.	2 wk.	3 wk.	Weight (lb.) 0	1 wk.	2 wk.	3 wk.
1	Control	13	2	7.5	7.0	5.9	....	3.5	5.3	7.0	....
	2 ml. dextrin-ferric oxide complex	34	1	6.5	10.7*	10.9*	....	3.8	6.4	8.9*	....
2	Control	24	0	7.5	7.5	5.0	4.8	3.8	6.6	8.5	9.6
	2 ml. Armidexan	21	0	7.5	6.7	9.5*	9.0*	3.6	6.8	9.1	11.3*
	2 ml. dextrin-ferric oxide complex	22	0	8.0	8.6	8.1*	7.8*	3.6	6.7	9.5	11.9*

[a] Location of test—New York State.
* Statistically significant at least 5% level.

TABLE 5. EFFECT OF SINGLE AND DOUBLE INJECTIONS OF DEXTRIN-FERRIC OXIDE COMPLEX IN TREATING PIGLET ANEMIA [a]

Treatment	No. pigs	Hemoglobin (gm. %) Pre inj.	1 wk.	2 wk.	3 wk.	4 wk.	Body weights (lb.) Pre inj.	1 wk.	2 wk.	3 wk.	4 wk.
Untreated	24	7.5	7.5	5.0	4.8	4.2	3.8	6.6	8.5	9.6	10.9
2 ml. dextrin-ferric oxide complex	22	8.0	8.6	8.1*	7.8*	7.2*	3.6	6.7	9.5	11.9*	13.6*
2 ml. dextrin-ferric oxide complex repeated at 14 days	16	8.3	9.0*	8.9*	10.5*†	9.3*†	3.8	6.5	9.1	11.5*	14.3*

[a] Location of test—Bullville, N. Y.
* Significant at 5% level with control.
† Significant at 5% level with single injection group.

the chloride concentration of the solution was decreased below the toxic level and essentially all iron present was converted to the sol form.

The dextrin-ferric oxide complex possessed the necessary chemical stability to pH changes, high ionic strength, heat sterilization and compatibility with tissues and tissue fluids for an acceptable product for parenteral use.

In the biological systems it was determined that the iron was in a form which was released and therefore available for hemoglobin synthesis. On the basis of the toxicity data, free ionic iron was not released in appreciable quantity from the injection site, otherwise toxic manifestations would be encountered. Therefore, the dextrin-ferric oxide complex appears to act as a self-transporting agent in the plasma independent of the iron-protein transport system.

Summary and Conclusions

Data have been presented on the preparation and biological testing of a dextrin-ferric oxide complex suitable for parenteral administration. The data indicate the material has low toxicity, is compatible with tissues and tissue fluids and is effective in treating the simply hypochromic anemia of pigs, with maintenance of hemoglobin levels and frequently superior weight gains.

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VARIATIONS IN BODY COMPOSITION OF MICE HAVING THE SAME AVERAGE DAILY GAIN [1]

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KNOWLEDGE of the body composition of animals (Lawes and Gilbert, 1859; Haecker, 1920; Mitchell and Carman, 1926; McMeekan, 1940) and some of the factors which influence it have been pointed out by Moulton *et al.* (1922) Ritchie *et al.* (1923) Hogan *et al.* (1927) and Crampton *et al.* (1954). Several methods of determining body composition have been studied (Hazel and Kline, 1953; Wellington *et al.*, 1956; Pearson *et al.*, 1957); however, the possibility that the same average daily gain may be resulting in animals with different body composition has had little study. Since in meat animals the production of meat is the major goal, the final composition of the animal is of great importance. The present study was designed to compare the body composition of animals that had made the same average daily gains. Because of their adaptability to analyses of the entire body, weanling mice were used as the experimental animals.

Experimental Procedure

Data for this report were taken from three experiments conducted with CF strain mice to test the effect of variation of diet upon body composition. Out of the total of 202 mice used in the experiments, 13 groups of females and 11 groups of males contained 3 or more mice that had made the same average daily gains. The first experiment consisted of 64 weanling mice allowed to eat *ad libitum* for 21 days in groups of four animals each, using four replications of four diets blocked on weight and sex. The diets used and their proximate analyses are shown in table 1. The second experiment consisted of 48 weanling mice in three replications which for 23 days were allowed to eat *ad libitum* the same four diets used in the first experiment. In the third experiment 90 weanling mice were individually caged and allowed to eat *ad libitum* for 21 days one or the other of diets 1 and 2 used in the first two experiments. Conventional feeding and management procedures were used. Average daily gains were based on weights to the nearest 0.1 gram at the beginning and end of the experiments. Moisture, fat and protein were determined on all of the animals. In the first experiment, the total dried animal body, less the contents of the digestive tract, was analyzed for fat by the AOAC (1955) procedure,

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[2] The authors are grateful to the Chas. Pfizer & Company, Inc., Terra Haute, Indiana for supplying products used in the study and to M. L. Coston for technical assistance.

except that preliminary grinding was not employed. Anhydrous ether extraction for 4 hours at condensation rates of 5–6 drops per second permitted complete extraction of the dried bodies wrapped in doubled filter papers. The fat was calculated by weighing the extract after drying. Protein was determined on the entire fat-free, moisture-free body by the boric acid modification of the AOAC (1955) procedure. In the second and third experiments the same procedures were followed with the exception that the animals were eviscerated. Moisture was determined in the first and third experiments by drying in a convection-type oven for 48 hours at 100° C., and in the second experiment by drying to constant weight in the same oven at 70° C.

TABLE 1. PERCENTAGE COMPOSITION AND PROXIMATE ANALYSES OF DIETS

Diet number	1	2	3	4
Ingredient				
Corn (8.7% protein)	42.48	79.32	91.31	54.07
Soybean oil meal, solvent (49.94% protein)	47.39	10.54	8.69	45.93
Cottonseed oil	10.13	10.14	.....	.....
Vitamin additions[a]	+	+	+	+
Mineral additions[b]	+	+	+	+
Analysis				
Moisture	8.80	9.47	10.94	8.93
Ether extract[c]	12.02	13.31	3.97	2.67
Protein	27.62	12.21	12.28	27.78
Crude fiber	2.06	2.39	2.30	1.47
Ash	4.98	4.06	3.97	5.21
Nitrogen-free extract	44.52	58.56	66.54	53.94

[a] Added per kilogram: Vitamin A, 20,000 USP units; vitamin D_2, 2000 USP units; riboflavin, 44 mg.; niacin, 264 mg.; pantothenic acid, 44 mg.; choline chloride (25%), 1.65 mg.; vitamin B_{12}, 33 mcg.

[b] Added per kilogram: Ground marble, 5 gm.; defluorinated phosphate, 5 gm.; and salt, 10 gm.

[c] Because of error in analysis and a loss of samples, it has been necessary to calculate ether extract on the basis of average composition of ingredients used in the diets.

Results and Discussion

Table 2 shows the variation in body fat, protein and moisture contents of the animals having the same average daily gains. Among the males, the fat component was the most variable, the coefficients of variation for the different groups ranging from 0.36 to 0.90. The coefficients of variation for protein content were less variable but were greater than 0.39 in all cases, and those for body water were 0.30 or more. Wider differences in fat content seemed to occur between females than males. The coefficients of variation for fat content of groups of females having the same gain varied from 0.29 to 0.65; those for protein content varied from 0.43 to 0.50, and those for water content from 0.30 to 0.33.

Differences of such magnitude as shown in these studies evidently reflect

TABLE 2. VARIATION IN BODY COMPOSITION OF MICE HAVING THE SAME AVERAGE DAILY GAIN

	Males										
Average daily gain, gm.	0.39	0.47	0.50	0.51	0.53	0.55	0.59	0.60	0.62	0.68	0.72
No. of mice	4	3	3	5	3	3	4	4	4	4	3
Mean fat, %	4.69	7.65	8.38	5.95	5.05	7.39	9.21	6.48	7.46	10.16	11.63
Min. fat, %	3.74	7.11	6.90	3.94	4.60	6.84	6.39	5.41	6.71	6.45	8.31
Max. fat, %	6.11	8.48	10.70	8.15	5.47	8.31	14.13	7.33	8.50	14.46	13.88
C. V.	.903	.554	.506	.712	.839	.573	.460	.654	.568	.417	.364
Mean protein, %	18.31	20.63	18.72	18.79	20.08	18.83	18.10	19.03	19.73	18.21	17.85
Min. protein, %	17.93	20.51	17.98	17.07	18.36	18.51	17.23	18.27	18.62	17.71	16.83
Max. protein, %	18.77	20.85	19.46	19.93	21.49	19.15	19.72	19.81	21.00	18.75	18.73
C. V.	.440	.391	.431	.429	.401	.428	.445	.424	.409	.443	.452
Mean water, %	71.50	67.50	67.79	70.68	70.06	69.04	67.56	68.83	68.83	65.94	66.46
Min. water, %	70.42	66.93	65.29	68.04	68.14	68.61	68.01	67.76	67.53	61.56	63.91
Max. water, %	72.94	68.29	69.10	72.17	71.79	69.38	70.57	71.02	69.39	69.63	68.52
C. V.	.299	.317	.316	.303	.305	.310	.317	.311	.313	.324	.322

	Females												
Average daily gain, gm.	0.31	0.40	0.42	0.43	0.45	0.46	0.47	0.48	0.51	0.53	0.60	0.61	0.70
No. of mice	3	3	4	3	3	8	3	5	3	4	3	3	3
Mean fat, %	11.16	7.67	10.43	6.54	7.48	9.91	7.53	9.06	13.56	8.96	14.62	13.99	9.85
Min. fat, %	6.71	6.52	6.95	5.40	4.04	5.74	5.33	7.52	10.58	5.85	9.81	8.95	7.71
Max. fat, %	15.88	8.29	15.73	8.23	10.78	18.59	11.28	11.19	15.30	11.10	18.32	17.77	11.99
C. V.	.380	.550	.406	.648	.566	.428	.563	.468	.312	.473	.290	.303	.430
Mean protein, %	16.16	18.04	17.51	18.71	17.31	17.36	18.90	18.73	16.73	18.07	16.14	16.63	17.58
Min. protein, %	14.50	17.16	16.59	17.64	16.26	16.49	16.57	18.03	14.91	16.69	15.35	16.04	17.44
Max. protein, %	17.35	18.67	19.22	19.38	18.07	17.92	20.56	19.51	18.78	19.12	16.68	17.44	17.72
C. V.	.499	.447	.460	.431	.466	.464	.427	.430	.482	.446	.499	.485	.459
Mean water, %	67.09	69.82	66.61	70.19	70.39	67.95	68.38	67.28	65.06	67.83	64.86	64.78	66.47
Min. water, %	61.45	68.82	62.69	68.83	67.34	60.82	65.48	64.60	63.64	66.20	60.94	61.23	64.75
Max. water, %	72.08	70.99	69.70	71.64	74.42	71.82	70.09	69.49	65.88	70.66	68.56	68.58	69.02
C. V.	.319	.306	.321	.305	.304	.315	.313	.318	.329	.315	.330	.330	.322

real differences in the fat content of animals having the same average daily gains. The five groups of females and three groups of males in which minimum and maximum fat content differed by more than 100%, as well as those groups in which the variation was less, give strong support to such a conclusion. Less striking but consistent and evidently real differences in protein and moisture content can also be noted.

Attention should be called to the wide variation in the composition of the diets fed. Since the purpose was to compare the body composition of animals having the same average daily gain, dietary treatment was not made a basis of comparison.

Summary

Albino mice in groups of three or more which had made the same average daily gains on a corn-soybean type diet (*ad libitum*) were compared as to final body composition, moisture, fat and protein. Coefficients of variation for the fat content of the groups of males having the same gain varied from 0.36 to 0.90. The coefficients of variation for protein were at least 0.39 in all cases and for moisture at least 0.30. In females having the same gain, the coefficients of variation for the fat content varied from 0.29 to 0.65, for protein from 0.43 to 0.50 and for moisture from 0.30 to 0.33.

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EFFECT OF VARIOUS ENERGY SUPPLEMENTS ON GAINS, YIELDS AND CARCASS GRADES OF LAMBS GRAZING ALFALFA PASTURE [1]

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THE intake of TDN by the grazing animal is limited largely by the bulk or ballast of the forage (Crampton, 1952). If this is true, then feeding energy supplements to feeder lambs being fattened on pasture seems a reasonable management practice in attempting to obtain choice lambs in a shorter period of time and perhaps at lighter weights. Diggins and Bundy (1958) make precisely this recommendation. McClymont (1956), however, presents evidence that the actual response obtained from supplements was about 30% of what might be expected on the basis of the energy consumed and cites unpublished data that show a reduction in pasture intake caused by supplementary feeding that is not confined to poor pasture. Experiments conducted by Miller (1941) support McClymont findings, but also show that supplemented lambs had more finish and produced a larger number of choice carcasses. Lofgreen *et al.* (1960) found that an energy supplement fed at the rate of 0.5 lb. per 100 lb. body weight to steers receiving alfalfa soilage would significantly increase daily gain, carcass grade and carcass yield. A higher rate of supplementation (0.7 lb. per 100 lb. body weight) did not significantly stimulate daily gain above the 0.5 lb. level of supplementation, although the energy content of the gain was apparently increased. Roughage consumption decreased with each increasing increment of supplementation. More evidence of the quantitative response to supplementary feeding is necessary to form a basis for advice on the practice.

The following experiments were designed to determine the effect of various energy supplements on the rate of gain and market characteristics of fattening lambs grazing irrigated alfalfa pasture.

Experimental

1957–58 Trial. Ninety western feeder lambs were individually identified by ear tattoo and corresponding paint brand, then, randomly lotted and assigned to the treatments. In addition to the control lambs on alfalfa pasture alone, the treatment groups consisted of lambs supplemented with either molasses, ground barley, or pellets. The pellets consisted of alfalfa containing concentrate levels of 0, 30, and 60%. The concentrate was a

[1] Acknowledgement is made of the assistance of the late Nicholas R. Ittner under whose direction a portion of the 1957–58 trial was conducted.

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mixture of three parts barley to one part molasses dried beet pulp. The pellets, ¼ in. in diameter, were made after the concentrate and hay had been finely ground through a 1/16-in. screen.

The molasses was fed free choice and all other supplements at the approximate rate of 1 lb. per head per day. The lambs were confined to a pasture of sufficient size so that a new area would be required in 10 to 14 days. An effort was made to have equal grazing intensity in all lots; therefore, the supplemented lambs received less pasture area than was required by the controls. A commercial lamb buyer topped out the choice lambs after 60 days; all remaining lambs were marketed after 88 days. Warm carcass weights and U.S.D.A. grades were obtained at slaughter. All lamb weights were recorded in the early morning after a 12-hour stand in drylot without feed or water.

1958–59 Trial. This trial was similar in design to the 1957–58 trial and conducted in the same pasture field; however, there were certain differences. Ninety-six lambs were used and all supplemented lambs were allowed the supplement free-choice. Pasture samples were taken before and after a pasture was grazed to provide information on relative grazing intensities. The samples were obtained with a small sickle-bar type mower equipped with a device to catch all clipped material. The cutter bar was set to cut 1 in. above the surface of the field. A strip 3.5 ft. by 100 ft. was cut from each area before grazing. The clipped sample was weighed immediately and approximately 5 lb. saved for the determination of dry matter and for chemical analysis. Immediately after the lambs were moved to a new area, a strip 3.5 ft. wide was cut the entire length of the previously grazed pasture (500–600 ft.) and sampled as before. Samples were dried at 95° C. in a forced-air oven, ground and retained for chemical analysis.

A commercial lamb buyer topped out the choice lambs after 80 days; the remainder were on trial for 104 days.

Results and Discussion

A summary of the gain and carcass data from both trials is shown in table 1. The results of the analysis of variance (Snedecor, 1956) and the Duncan multiple range test (LeClerg, 1957) are indicated by the use of subscripts or superscripts.

There were no significant differences in daily gains between treatment groups during the 1957–58 trial where the supplements were fed in limited amounts. The pellet-supplemented lambs had significantly greater yields and in general a larger percentage of the carcasses graded choice. They reached market an average of 6 days sooner than control lambs. Lambs supplemented with barley or molasses had higher average dressing percentages than controls, but little difference in the number of choice lambs produced and only a three-day advantage in time to market.

During the 1958–59 trial free choice of supplement was permitted. The lambs receiving the 30% concentrate pellet showed significantly ($p<.05$)

TABLE 1. RESPONSE OF LAMBS GRAZING ALFALFA PASTURE AND FED DIFFERENT ENERGY SUPPLEMENTS

			Pellets[e]									
	Control		Alfalfa 100%		Alfalfa 70% Conc. 30%		Alfalfa 40% Conc. 60%		Ground barley[e]		Molasses	
Treatment and year	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59
Number of lambs	15	16	15	16	15	16	14[g]	16	14[g]	16	15	16
Av. days fed[f]	84	98	79	96	77	90	78	95	80	102	82	99
Av. initial wt., lb.	72.2	68.1	72.1	68.4	72.8	68.2	72.3	66.6	71.3	66.8	74.8	67.9
Av. final wt., lb.	106.4	108.9	106.3	112.8	105.0	113.1	106.8	110.3	102.8	107.9	106.2	111.5
Av. daily gain, lb.	0.40	0.42^{ab}_{a}	0.43	0.46^{bc}_{b}	0.42	0.50^{c}	0.44	0.46^{bc}_{b}	0.39	0.40^{a}_{a}	0.38	0.44^{ab}_{ab}
Av. daily gain, lb. (combined years)	0.41^{ab}		0.45^{bc}_{a}		0.46^{c}_{a}		0.45^{bc}_{a}		0.40^{a}		0.41^{ab}	
Supplement consumed, lb./head/day	0	0	0.87	1.46	0.90	1.66	0.88	1.67	0.56	1.00	0.11	0.21
Av. carcass yield[h]	52.2^{a}_{a}	52.4	53.6^{bc}_{bc}	52.5	54.6^{c}_{d}	52.9	53.7^{bc}_{bcd}	53.4	53.6^{bc}_{bcd}	53.2	53.2^{b}_{bc}	53.6
Av. carcass yield[i] (combined years)	52.3^{a}		53.1^{ab}		53.7^{b}		53.5^{b}		53.4^{b}		53.4^{b}	
U.S.D.A. carcass grades:												
Choice, %	27	44	53	56	67	94	64	62	43	69	34	75
Good, %	73	56	47	44	33	6	36	38	57	31	60	25
Utility, %	..	..	..	..	..	..	..	..	..	..	6	..

[a, b, c, d] Statistical notations. Differences are significant if values being compared do not have a common subscript ($p<.05$) or superscript ($p<.01$). No letter or the same letter on comparable values indicates no significant difference.

[e] Limited-fed 1957–58; full-fed 1958–59.

[f] 1957–58 lambs topped at 60 days, remainder at 88 days; 1958–59 lambs topped at 80 days, remainder at 104 days.

[g] One lamb died from causes not associated with experimental treatment.

[h] Warm carcass weight divided by the final experimental weight.

[i] Significant ($p<.05$) year x treatment interaction.

greater gain than all other groups, reached market an average of 8 days ahead of the controls and produced twice as many choice animals. The other pellet-supplemented lambs significantly out-gained the controls and showed a little advantage in carcass grade but required approximately the same number of days to market. There were no significant differences in gains between controls and those supplemented with barley or molasses, although there were more choice lambs in the supplemented groups. There were no significant differences in carcass yields during the 1958–59 trial.

Combined analysis of the data from the two trials indicates that the pellet-supplemented lambs made significantly greater ($p<.05$) gains than the controls and also greater gains than those supplemented with barley or molasses. The combined data on yields indicated a significant ($p<.05$) year x treatment interaction; however, at the higher level of significance

TABLE 2. ESTIMATED FORAGE CONSUMPTION AS DETERMINED BY SAMPLING THE PASTURE BEFORE AND AFTER GRAZING

Treatment	Pounds (dry matter)			Pounds (dry matter)		Area grazed [c]	
	Total forage available [a]	Total forage refused [b]	Percent refused	Total forage consumed	Forage consumed (av./ head/day)	Total acres	Per lamb per day (sq. ft.)
Pasture	7431	1063	14.3	6368	4.06	7.02	195.0
Pasture+ pelleted alfalfa	4360	798	18.3	3562	2.31	4.12	116.2
Pasture+30% conc., 70% alf. pellets	4952	805	16.3	4147	2.86	4.68	140.7
Pasture+60% conc., 40% alf. pellets	3744	890	23.8	2854	1.87	3.54	99.8
Pasture+barley	4467	955	20.4	3512	2.14	4.21	111.8
Pasture+molasses	6690	725	10.8	5965	3.75	6.32	172.9

[a] Composite sample: 4.4% lignin, 3.5% nitrogen.
[b] Composite sample: 6.5% lignin, 2.1% nitrogen.
[c] Standardized on the basis of the average dry matter available per sq. ft. (0.0243 lb.)

($p<.01$) the lambs fed the more concentrated supplements (barley, molasses, 30% concentrate pellets and 60% concentrate pellets) out yielded the control animals.

A summary of the results from the pasture sampling procedure undertaken during the 1958–59 trial is shown in table 2. It is widely recognized that sampling a pasture before and after grazing is not an entirely adequate measure of the quantity or quality of the consumed forage. (Hardison *et al.*, 1954; Peterson *et al.*, 1956; Meyer *et al.*, 1957; Weir and Torell, 1959). However, the procedure does give some information about the relative grazing intensity between treatments and an estimate of the amount of forage consumed. In general the lambs consumed approximately 4 lb. of dry matter per day. The supplemented lambs (molasses excepted) consumed 60 to 70% of their dry matter from pasture.

The control lambs averaged over 0.4 lb. per day gain which would indicate a high quality forage was being consumed. The alfalfa was generally quite lush and averaged 20.2% dry matter. Bloat was not a problem

in either trial. Chemical analysis of the clipped "before grazing" composite samples indicated a lignin content of only 4.4% (footnote table 2). The regression equation between lignin and TDN given by Meyer and Lofgreen (1959) would indicate a TDN content of 67% for alfalfa containing so small a percentage of lignin.

Table 3 is a summary of calculations indicating the efficiency of the supplements in producing lamb. In these calculations it is assumed that supplemented lambs utilized pasture as efficiently as the control lambs. This assumption may not be completely correct since all supplemented lambs except the molasses group refused from 2 to 9% more of the available forage than did the control lambs (see table 2); however, errors in pasture management would also be involved in this refused forage figure. The supplement required for each pound of gain, when fed in a limited amount during 1957–58, is considerably greater for the two pelleted supplements containing concentrate, and for barley, than that which might be considered economical. Lambs fed the all-alfalfa pellet produced a pound of gain almost as efficiently as lambs fed a pellet of similar composition in drylot (Weir *et al.*, 1959; Meyer *et al.*, 1959). The free-choice, molasses-supplemented groups received comparatively little energy from molasses, but the apparent efficiency of utilization was good each year.

When supplements other than molasses were fed on a free-choice basis the efficiency of feed utilization as measured by the supplement required per pound of gain was equal to or below that which one might expect of the same feed in drylot conditions. It would appear from these data that in instances where supplementation of lambs being fattened on pasture is indicated the more efficient practice in terms of feed utilization would be to permit free-choice consumption of the supplement. However, the interpretation of the data on the basis of average daily gains or feed per lb. of gain can be misleading in instances where the chemical composition of the gain may not be similar for all treatments (Garrett *et al.*, 1959). Calculations by Lofgreen *et al.* (1960) illustrate this point in a trial with beef steers. In the lamb trial reported here, both a moderate level (50 to 60% of *ad libitum*) and *ad libitum* consumption of the various supplements produced more choice lambs than pasture alone. The differences were greater when the supplements were fed free-choice. The higher proportion of choice animals indicates fatter carcasses and thus a higher energy content of the gain for the supplemented animals, even though average daily gains were not significantly different in some comparisons. This result is similar to that obtained with steers by Lofgreen *et al.* (1960).

The amount of the supplemental feed required to produce a pound of lamb (after correction for lamb produced from pasture) when the supplements were fed free-choice did not appear to be in excess of that required in dry-lot; however, a commercial feeder must determine if the increased daily gains and/or improved carcass grades would be sufficient to balance completely the cost of the supplement. Under the economic situation that

TABLE 3. COMPARATIVE EFFICIENCY OF VARIOUS SUPPLEMENTS FED IN LIMITED AMOUNTS OR FREE CHOICE TO LAMBS GRAZING ALFALFA PASTURE [a]

	Average per lamb														
	Acres grazed [b]		Lamb days from past. [c]		Lamb from past. [d] (lb.)		Total lamb (lb.)		Lamb from supplement (lb.)		Supplement consumed (lb).		Supplement per lb. of gain		
Item	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	57–58	58–59	58–59 [e]
Alfalfa pellet	0.285	0.259	67	58	27	24	34	44	7	20	69	140	9.8	7.0	6.5
30% Conc. pellet	0.289	0.292	68	65	28	27	32	45	4	18	69	149	17.2	8.3	8.1
60% Conc. pellet	0.292	0.221	68	49	28	20	34	44	6	24	69	159	11.5	6.6	6.3
Barley	0.304	0.264	72	59	29	24	31	41	2	17	45	102	22.5	6.0	5.5
Molasses	0.295	0.395	70	88	28	37	31	44	3	7	9	21	3.0	3.0	3.9

[a] Supplements limited-fed 1957–58; full-fed 1958–59.
[b] Acres grazed per control lamb: 1957–58, 0.36; 1958–59, 0.44.
[c] Assumes same carrying capacity per acre as control lambs: 1957–58, 236 lamb days; 1958–59, 223 lamb days.
[d] Calculated using average daily gain made by control lambs.
[e] Calculated for comparison from estimated forage consumption data, table 2.

existed during these trials, it would have been more profitable to utilize the pasture alone.

Summary

Limited, or free choice amounts of various energy supplements (alfalfa pellets, 30% concentrate pellets, 60% concentrate pellets, barley, or molasses) were fed to lambs grazing alfalfa in the Imperial Valley of California during two successive years. When fed in limited amounts none of the supplements significantly increased average daily gain, although there was an advantage of greater yields and more choice carcasses. Free choice of the supplement resulted in significant increases in average daily gain of pellet-supplemented animals over the controls with some advantage in carcass grade for all supplemented animals. When pasture and a supplement were available free-choice, the supplement required to produce a pound of lamb was not in excess of the amount ordinarily required of the same feed under drylot conditions.

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DESIGN AND USE OF A MILKING MACHINE FOR SOWS

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LIMITED data are available concerning the lactation performance of swine. The studies to date have been made by weighing the pigs, individually or as a litter, before and after nursing at pre-determined intervals, the gain in weight being accepted as a measure of the amount of milk suckled (Schneider, 1934; Bonsma and Oosthuizen, 1935; Smith, 1959a, 1959b).

Few detailed studies have been made of the composition of sow's milk. This is probably because it has been difficult to obtain adequate samples by manual expression. Before Ely and Petersen (1941) demonstrated the use of oxytocin as a method to induce milk let-down in the cow, samples were obtained by quietly removing a nursing pig and milking the vacated teat by hand. The difficulty with this method has been mentioned by nearly all of the early workers (Henry and Woll, 1897; Woll, 1899; Carlyle, 1903; Hughes and Hart, 1934). Milk samples can be obtained by injecting oxytocin into an ear vein and milking by hand (Braude *et al.*, 1947; Bowland *et al.*, 1949), but only a few teats can be milked because of the limited time of milk flow.

Milking machines for sows have been developed by Smith *et al.* (1951) and Lodge (1957a). Smith (1952a, 1952b, 1959a, 1959b), Perrin (1954) and Lodge (1957b) have reported the use of a machine for obtaining milk samples for composition studies, but not for measuring total yield.

A milking machine for sows was developed to collect data which could be used to study lactation performance and to determine the factors affecting milk yield and composition. This machine makes it comparatively easy to collect milk separately and simultaneously from all functional glands.

Materials and Methods

Design of the Milking Machine. The machine consists of a 2-unit De Laval vacuum pump, two standard De Laval milk pails and pulsators,[1] and two racks each of which holds six 1-pint milk bottles to which the vacuum line and teat cups are attached (figure 1). Fifteen inches of vacuum and a pulsation rate of 70 per minute were used in this study. A standard, 1-in. O.D.[2] rubber tube vacuum line was used to connect the vacuum pump to a pulsator located on each side of the farrowing crate.

The double line vacuum tube was approximately 4 ft. long. Five ⅜-in. O.D. copper T's were spaced 6 inches apart with a 90 degree elbow attached

[1] Acknowledgment is made to the De Laval Separator Company, Poughkeepsie, N. Y. for use of their equipment.
[2] O.D. is outside diameter; I.D. is inside diameter.

to the end of each vacuum line. Six 36-in. pieces of ¼-in. I.D. rubber tubing connect the "T" and "L" joints to the stems of the teat cups. This causes pulsation in alternate teat cups.

The large vacuum line from the pail lid was connected by a ⅜-in. reducer to a line of five ⅜-in. O.D. copper T's spaced 2.5 inches apart with a 90 degree elbow on the end. These were attached by 3 in. of ¼-in. I.D. rubber tubing to six ⅛-in. air cocks. Eight inches of rubber tubing were used to connect the air cocks with 3 in. of ⅜-in. O.D. leucite tubing which was inserted through a No. 7 rubber stopper fitted into the milk bottle. A

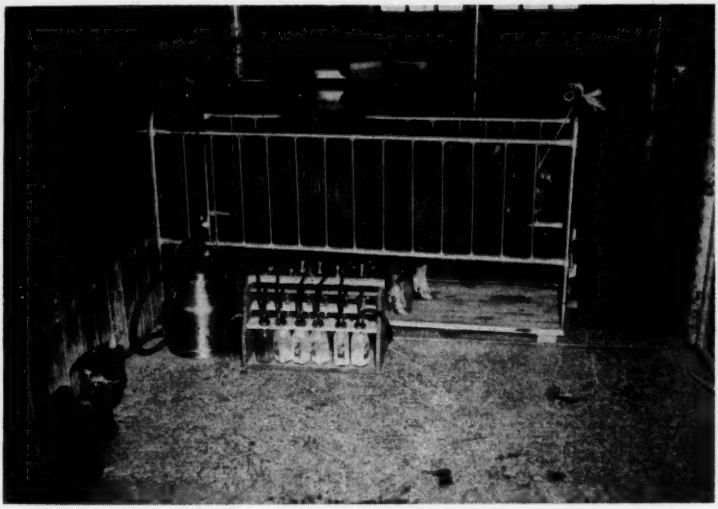

Figure 1. A milking machine for sows.

second leucite tube was inserted through the rubber stopper and was connected to 36 in. of ¼-in. rubber tubing which connected to the teat cup.

The teat cups were made of ¾-in. I.D. brass tubing 2⅜ in. long. A copper tube 1.5 in. long and ¼ in. I.D. cut at a 35 degree angle was soldered over a hole in the casing which was cut at the same angle. A ring was made of 3/32-in. solid wire, fitted snugly into the topmost part of the casing, and soldered, giving it an I.D. of 9/16 in. Two smaller sizes of teat cups were made by filling in the rings with paste-type aluminum solder, allowing it to harden and then filing it back to 7/16 and 1/2 in. I.D. The fourth and largest size of teat cup (¾ in. I.D.) was made by using the casing without a ring.

The teat cup liner was made of ⅝-in. I.D. pure gum flexible rubber tubing with a 1/16-in. thick wall. The liner (4 in. long) was inserted

through the casing and folded back snugly over each end. The lower ¼ in. of a No. 6 cork stopper was cut off and bored so that a 1¼-in. length of 5/16-in. O.D. copper tubing fitted snugly through it. A hole 3/64 in. in diameter was bored through one wall of the copper tubing near the cork stopper to allow entrance of the amount of air necessary to keep the line from flooding with milk. The cork stopper was given several coats of Glyptal [3] to insure a good seal when pressed into the bottom of the teat cup.

By use of the air cocks any number of teat cups may be used without the loss of vacuum. Since sows may have several teats that are smaller or larger than the others, it is usually necessary to have available teat cups of four different sizes.

Milking Procedure. The sow to be milked is driven into a farrowing crate and tied by a rope around her maxilla behind her tusks. The udder is then washed free of dirt. To facilitate the injection of oxytocin,[4] a rubber band may be placed around the base of one ear to make the veins more prominent. Approximately 1.5 ml. of oxytocin is injected into a vein in the ear with a syringe fitted with a 20-gauge needle, and the rubber band is removed. The vacuum pump is started and teat cups are put on immediately. Within 30 seconds, milk let down begins and after 1 to 3 minutes, the rate of flow decreases sharply. As soon as the rate of flow starts to decline, a worker on each side of the sow massages the glands, a procedure which was found to increase the amount of milk by approximately 10%.

The lactation trends of a Berkshire and Yorkshire sow nursing litters of five and six pigs respectively were estimated by the use of the milking machine described. Milking was done one day weekly during the 1st and 4th through the 9th weeks of lactation. A 2-hour interval during which the pigs were not allowed to nurse preceded each machine milking. Pigs were ear-notched and the teat(s) which they nursed throughout lactation were recorded. The pigs were weighed during the 1st and 4th weeks of lactation to the nearest 5 gm. The sows were under normal herd management.

Results and Discussion

The data in table 1 were collected on one day during the first and fourth weeks of lactation as previously described. Pigs nursing the teats located more anteriorly tended to make the largest gains. Furthermore, the amount of milk obtained by machine tended to be greater from anteriorly located glands than from posterior glands. There was a positive correlation of $r=0.77$ between the weight gain of the pigs and the volume of milk obtained by machine milking.

Figure 2 indicates the lactation trends of these sows milked by machine during the 1st and 4th through the 9th weeks. Each value represents the

[3] Apparatus and Maintenance Paint, No. 1201, General Electric, Chemical Department, Pittsfield, Mass.

[4] Armour Purified Oxytocic Principle, 20 U.S.P. Units per ml.

TABLE 1. THE YIELD OF MILK OF A BERKSHIRE AND A YORKSHIRE SOW AS MEASURED DURING THE FIRST AND FOURTH WEEK OF LACTATION

Pig no.	Gain of pigs[a]	Teat nursed by pig[b]	Total milk obtained by machine at 1:00 p.m.[c]
	gm.		ml.
Berkshire sow			
2	5915	L1 & R1	663
3	4415	L2 & L3	286
5	3855	R2	212
1	3395	R3 & R4	368
6	2470	R5	136
Yorkshire sow			
5	5235	R1	400
3	4975	R2 & R3	428
1	4105	L2	220
4	6655	L4	381
2	2810	R4	44
6	3820	R7	112
Correlation with rate of gain			+.77

[a] During first four weeks.
[b] LI—L4 = teats on left side, front to rear, respectively.
RI—R7 = teats on right side, front to rear, respectively.
[c] The combined yield of single milkings during the 1st and 4th weeks from teats nursed by pigs listed.

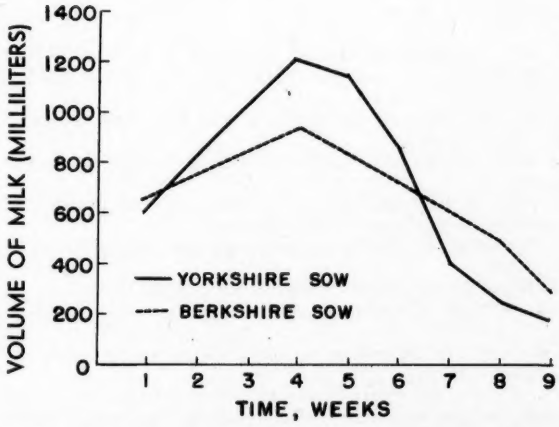

Figure 2. Lactation trends of sows as measured by machine milking during the 1st and 4th through the 9th weeks.

volume of milk taken after the injection of 1.5 ml. of oxytocin into the ear vein.

Some sows rebel against being tied by a rope and it has been necessary to select docile sows for machine milking. Some sows squeal loudly until the injection of oxytocin, but then express grunts as though nursing their pigs. A recording made of pigs squealing at nursing time may be of use in the milking procedure, since on one occasion the sow was coaxed into expressing deep grunts a second time by the workers imitating the sounds made by suckling pigs.

A dental syringe with a 30-gauge needle attached has been used on a limited basis to inject xylocaine [5] along an ear vein to numb that area, allowing the oxytocin to be injected easily with a 20-gauge needle. The sows were unaware of being injected with the large needle and little difficultly was experienced in injecting the xylocaine with the 30-gauge needle.

Summary

A milking machine for sows has been developed which collects milk separately and simultaneously from all functional glands. Its use for measuring the milk yield and for securing adequate samples for composition studies has been indicated on the basis of limited data.

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[5] Local anesthetic, Astra Pharmaceutical Products, Inc., Worcester, Mass.

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MEASUREMENT OF THE CROSS-SECTIONAL AREA OF THE LOIN EYE MUSCLE IN LIVE SWINE BY ULTRASONIC REFLECTIONS [1]

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IT has been shown that the thickness of various adipose tissue layers in living swine can be accurately measured by sound reflection methods. (Claus, 1957; Lauprecht *et al.*, 1957; Hazel *et al.*, 1959; Price *et al.*, 1960). Success in accurately measuring the depth of lean tissues has thus far been limited (Price *et al.*, 1960). However, with the advent of new innovations in ultrasonic generating and detecting equipment, greater penetration into living tissue and greater resolution of reflection peaks have been possible. Stouffer (1959) developed and described a method of plotting the cross sectional area of the loin eye muscle from ultrasonic reflection and angular readings for live meat animals.

This study was carried out to ascertain the accuracy of "ultrasonic muscle tracings" from live hog measurements taken as described by Stouffer (1959).

Materials and Methods

A series of ultrasonic reflection readings was taken on each of 41 hogs at different angles of incidence. The hair was clipped over the loin, just above the last rib on the right side of each pig. This area was marked off in inches, starting from the center of the back and moving down over the side of the animal. A piece of lead solder wire was formed to the contour of the back and the contour shape transferred to a sheet of paper. A Sperry Reflectoscope with a type Z, ½-inch diameter, 2.25 m.c. transducer (Branson Instruments, Inc.) was set so that 4 inches of aluminum corresponded to 1 inch on the oscilloscope scale. Direct readings of the depth in inches of the various tissue layers were then recorded at each inch mark on the back and in most cases halfway between marks to substantiate other readings. The readings were made at approximately 10 sites on each hog from ½ to 6 inches off the midline. With the tissue depth reading taken visually from the scope (Price *et al.*, 1960) at each mark, the angle of projection of the sound waves was noted by using a device as described by Stouffer (1959). By plotting the depth at the corresponding angle along the contour line, a picture similar to a cross sectional tracing of the

[1] Journal Article 2563 Michigan Agricultural Experiment Station.

[2] This paper reports a portion of the research completed by the senior author in partial fulfillment of requirements for the Ph.D. degree, School for Advanced Graduate Studies, Michigan State University.

[3] The authors gratefully acknowledge the cooperation of the following people: Mr. R. Y. Neiley, Sperry Products, Inc., Danbury, Conn., for furnishing the Sperry Reflectoscope used in this study; Mr. John E. Bobbin, Branson Instruments, Inc., Stamford, Conn., for providing the transducer used in the experiment; Mr. Russell G. Ives of the American Meat Institute for his encouragement.

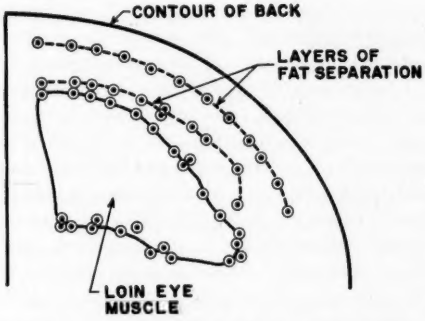

Figure 1. Actual plot of loin eye area taken at last rib.

loin at the last rib resulted (figure 1). The area of estimated eye muscle was measured with a compensating polar planimeter from the plotted outline.

The animals were slaughtered and cut as described by Cole (1951). A cross sectional tracing of the *Longissimus dorsi* muscle was made of the untrimmed loin immediately anterior to the last rib and the area was measured.

Analysis of variance and correlation analysis were used to ascertain the difference and relationship between the ultrasonically measured loin eye areas and corresponding tracings taken from the carcasses.

Results and Discussion

The means of the loin eye areas obtained by two methods are shown in table 1 along with standard deviations, F and r values. The means showed a tendency to over-estimate the eye muscle size from an ultrasonically determined plot. This could have been due to the machine setting, differences in muscle size in the live animal as compared to the carcass, or a tendency to sketch in a more rounding perimeter than actually existed. Incomplete resolution of tissue layers introduced some subjectivity in lean depth measurements. It was observed that three of

TABLE 1. MEANS, STANDARD DEVIATIONS, F VALUE AND CORRELATION COEFFICIENT FOR ACTUAL AND ESTIMATED LOIN EYE MUSCLE AREA

Comparison	Mean	Std. dev.	F value	Correlation coefficient
Area from plot	3.85 in.	0.64	2.57[a]	0.74[b]
Area from tracing	3.65 in.	0.58		

[a] F value indicated no significant difference at 5% level.
[b] Correlation coefficient significant at 1% level.

the areas were grossly overestimated (i.e., 0.95 sq. in. or more), while one was grossly under-estimated. The remainder of the area estimates fluctuated over and under the area of the corresponding tracing. The 0.2-sq. in. difference in the means of muscle area as measured by two methods was not statistically significant. The correlation between ultrasonically estimated loin areas and the actual area taken from tracings of 0.74 was of sufficient magnitude to be of value for predictive purposes.

A more comprehensive evaluation of this technique leads to a discussion of the inherent errors and some of the difficulties encountered. The velocity of ultrasound through animal tissues in the frequency range used becomes a factor when direct readings of depth are to be taken from a linear oscilloscope scale (i.e., the machine set for direct inch-depth measurement.) The velocity of ultrasound through aluminum has been shown to be 6220

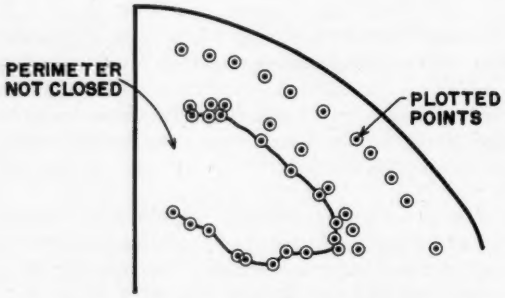

Figure 2. Actual plot of loin eye area, showing unclosed perimeter along spinal column.

meters per second. Ludwig (1950) reported a velocity of 1575 to 1585 m/s in boneless beef, and velocities of 1505 to 1558 m/s in the internal organs of hogs. Stouffer (1959) has assumed velocities of 1520 and 1420 m/s in the live animal and carcass, respectively. From regression equations computed at this station (Price *et al.*, 1960), it was found that the average velocity of pulsed, 2.25 mc. ultrasound was 1850 m/s in fatty tissues of living swine. It is readily apparent that for direct measurement of fat thickness a reflection peak for approximately 3.40 inches depth of aluminum should be set at 1.0 inch on a linear oscilloscope scale. For direct measurement of lean depth, the setting should be approximately 4.0 inches of aluminum corresponding to 1.0 inch on the scale.

Since hogs are neither all fat nor all lean, the selection of a machine setting is arbitrary. Values obtained for fat depth at a 4-inch aluminum to 1-inch scale setting are slightly different from actual. Since a layer of fat covers the lean muscles to be measured, slight errors are theoretically unavoidable. Also, it can be seen that errors of this type become greater

as fat thickness increases. A further problem is the fact that the velocity of ultrasound hinges upon the character and composition of the fat (Claus, 1957). Thus, the velocity may vary from one animal to another.

Assuming the errors introduced above to be negligible, it was found that upon plotting the points at corresponding angles an unclosed perimeter for the estimated eye muscle (figure 2) resulted. Thus, it was necessary to "draw in" subjectively the two ends of the loin eye muscle. Since the sound waves reflected from tissue layers that lie perpendicular to the projected beam are the only ones causing a strong peak on the oscilloscope, it was not possible to locate the exact position outline of the eye muscle adjacent to the backbone. Also, the lack of cooperation of the pigs during the tedious process of "sounding" was no ignorable problem. It would have been desirable to obtain duplicate or triplicate sets of readings on each animal, thus getting a repeatability estimate. The time involved and the fatigue of both the operator and animal made this impractical.

Summary and Conclusions

Estimates of the cross sectional picture of the loin in 41 live hogs were made utilizing ultrasonic reflection measurements coupled with angles of incidence at a scheduled series of sites over the last rib. Although some subjective judgment was necessarily involved in completing the "ultrasonic plots", the mean of these estimates of muscle size was not significantly different from the area of the loin eye muscle measured from tracings of the rough loin. The correlation between live estimated area and actual eye muscle area was 0.74. This method of determining muscle size in live swine was time consuming and tedious, thus its usefulness may be restricted for the present to research until further refinement in technique results in sufficient improvement in accuracy for predicting muscle size in breeding stock. Refinement of technique may increase the precision of this tool for measuring leanness in live animals.

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STUDIES ON BOVINE OCULAR SQUAMOUS CARCINOMA ("CANCER EYE") X. NUTRITIONAL EFFECTS

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A NUMBER of possible contributing factors influencing the development of "cancer eye" have been postulated, such as irritation of the eyes by dust, sand, insects and chemicals (see Russell *et al.*, 1956, for references). Sunlight may also be involved since eyelid pigmentation was shown to have a significant protective influence against the development of lesions in pigmented areas (Guilbert *et al.*, 1948; Bonsma, 1949; Anderson *et al.*, 1957; Anderson, 1959), the assumption being that pigment prevents the penetration of sunlight. A genetical basis for susceptibility, independent of the effects of eyelid pigmentation, was indicated by the observation that additive genetic differences account for 17 to 40% of the total phenotypic variability in susceptibility, and differences from allelic and nonallelic interactions for about 10% (Blackwell *et al.*, 1956; Anderson, 1959). Knox (1949) and Woodward and Knapp (1950) have likewise provided evidence of a genetical basis in this disease process. Finally, opinion has it that poor nutrition is a possible contributing factor because the disease seems more prevalent following periods of drought. This report will purport to show that contrary to this general belief, a low level of nutrition is less deleterious than a high level.

Materials and Methods

The project [2] from which the present data were obtained was conducted by the Oklahoma Agricultural Experiment Station to determine the effect of three levels of supplemental winter feeding on the lifetime production of beef cows. The project was begun in the fall of 1948, and since 1949 it has been conducted at the Ft. Reno Research Station [3] in El Reno, Oklahoma. One hundred and twenty choice Hereford weanling heifers, of

[1] Department of Biology. This is publication No. 10 of the Cancer Eye Study Section. The investigation was supported in part by Grant G–1 from the American Cancer Society, Grant C–1751 and C–2890 from the National Cancer Institute of the National Institutes of Health, Public Health Service. The author wishes to express his appreciation and gratitude to Doyle Chambers, Oklahoma State University, for his suggestions during the study; to J. L. Lush, Iowa State University, for his valuable criticisms and suggestions during the preparation of the manuscript; to E. S. Wynne, Department of Microbiology, Randolph Field, San Antonio, Texas, for the clinical and microscopic diagnosis of lesions; and, to L. S. Pope, Oklahoma State University, for his cooperation in providing the experimental animals.

[2] Detailed data on this project may be found in Okla. Agr. Exp. Stat. Misc. Pub. MP–19, 22, 27, 31, 34, 43, 45, 48 and 51 (1948 to 1959).

[3] Operated jointly by the Oklahoma Agricultural Experiment Station and the Agricultural Research Service, U.S.D.A.

which 105 were from one large commercial herd and 15 were from the experiment station herd, were divided on the basis of weight into one of three levels of feeding. The animals on the low level received 1 lb. of cottonseed cake per day; those on the medium level, 2½ lb.; and those on the high level, 2½ lb. plus 3 lb. of oats per day. The lowest level was considered to supply two-thirds of the digestible protein requirement of range beef cows, and the highest level to supply ample protein and energy. The animals were in their respective feeding groups from November 1 to mid April. They were rotated among winter pastures to minimize pasture differences, but grazed together during the summer. One-half of each group was bred to calve first as two-year-olds and the other half as three-year-olds, but this factor is disregarded in the present data.

Observations on cancer eye were started in April, 1954, and have continued at six-month intervals to the present. At each observation interval, eyes were examined clinically and photographed. The clinical examinations and interpretations of photographs were made by one person who also made the microscopic diagnoses when biopsies were taken (20% of the lesions were biopsied). The diagnoses were in accordance with the classification of Russell *et al.* (1956) wherein lesions on the eyeball, nictitating membrane, caruncle, and the lids were classified either as plaque, papilloma, keratoma, "boggy", or cancer.

The information from each observation pertained to the age at onset of lesions, their site of origin, progression or regression of the various types of lesions, and circumocular pigment. The ten sites where lesions were considered to originate included: (1) lateral limbus; (2) medial limbus; (3) superior limbus; (4) inferior limbus; (5) nictitating membrane; (6) caruncle; (7) medial half of the upper lid; (8) lateral half of the upper lid; (9) lateral half of the lower lid; and (10) medial half of the lower lid including the lacrimal lake.

Preliminary analyses indicated that the number of sites affected by squamous carcinoma and its benign precursor lesions was a better measure of variability in susceptibility at any one observation than was the most advanced lesion per animal, although the latter was used for one comparison. Age at onset was not satisfactory owing to observations on cancer eye commencing when the animals were 6 years of age, when many of them already had lesions. The number of affected sites was determined for each animal by merely summing the number in each eye. This number is not the same as number of lesions because one lesion may extend to involve more than one site, or there may be more than one lesion per site, particularly in the lid area. The number was found to range from 0 to 14.

Circumocular pigment was measured as an amount by determining the percentage of the entire lid length covered by pigment on a scale which divided lid length into 100 equal units.

The analysis pertains to 105 animals for which seven consecutive

observations were available in April, 1957. Of the original animals in the three nutritional levels, 28 remained in the low, 53 in the medium, and 24 in the high group for inclusion in the present study. There were 30 original animals in the low, 60 in the medium and 30 in the high. Relatively more disposals had occurred in the high than in the other two groups, but an interaction as large or larger than that observed between level of feeding and number of disposals would be expected by chance about 20 to 30% of the time. Disregarding of these disposal animals, therefore, should not have imposed any noteworthy bias in the analyses or results.

Results

The average number of sites affected by cancer and its benign precursor lesions was computed for each age and feeding level. These are tabulated in table 1. The averages were then plotted, as in figure 1, and to these,

TABLE 1. THE AVERAGE NUMBER OF SITES AFFECTED BY CANCER EYE LESIONS PER AGE AND FEEDING LEVEL

	Age (years)							
Winter feeding level	6	6½	7	7½	8	8½	9	Average
Low	0.50	0.61	0.72	0.89	1.00	1.18	1.07	0.85
Medium	.60	.78	1.00	1.40	1.51	1.46	1.79	1.22
High	1.12	1.25	1.50	1.84	1.92	2.29	2.12	1.74

linear regression lines were fitted by the method of least squares.[4] Second degree polynomials were also fitted but were rejected owing to an insignificant reduction in the sums of squares.

Table 1 and figure 1 show that level of feeding affects cancer eye importantly. The average number of affected sites at each age is highest in the high nutritional level, followed in order by the medium and low groups. The average number over all ages is 1.7 for the high, 1.2 for the medium, and 0.8 for the low level. The rates of increase in number of sites with each six-month increment in age are shown by the regression coefficients in the equations for each line in figure 1. The rates of 0.19 for the high, 0.20 for the medium, and the 0.12 for the low levels are significantly different from zero ($P<.01$). The rates of increase in the high and medium levels are significantly higher ($p<.05$) than in the low level; whereas the rates in the high and medium levels differ no more than would be expected by chance. The equations in figure 1 also show that the vertical intercept of the lines at the point of origin is highest for the high feeding level (.94), followed in order by the medium (.43), and low level (.39), indicating that a difference in feeding was already having effects on the occurrence of cancer eye at 5½ years of age.

[4] The author is indebted to Mr. Philip Skinner for his assistance in these computations.

The relative number of animals having lesions is also influenced by level of feeding as reflected by the following percentages (and standard errors): high level, 64 ±10; medium level, 59 ±7; and the low level, 43 ±9. Coupled with these findings is the one that the pathogenesis of lesions is also slightly more advanced in the high than in the other feeding

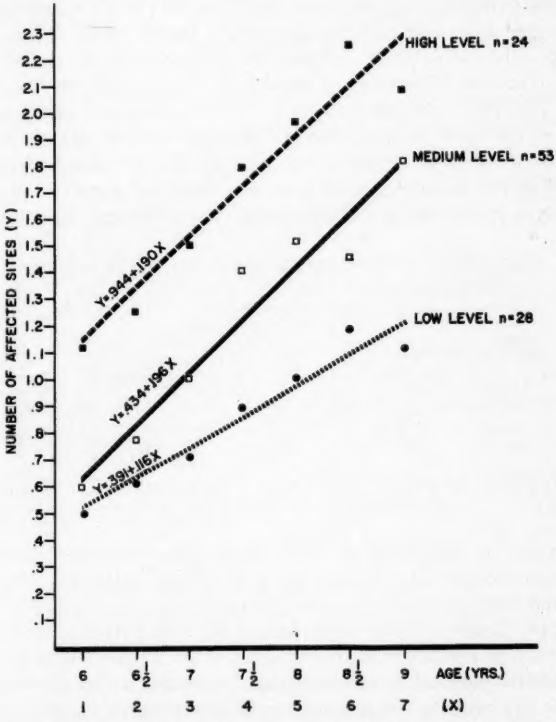

Figure 1. Number of sites on the eyes affected by cancer eye lesions as related to feeding level and to age.

levels. An animal's most severe lesion was arbitrarily scored as follows: normal, 0; keratoma and "boggy", 1; plaque, 3; papilloma, 4; and cancer, 5. The averages thus obtained were 1.8 for the high, 1.7 for the medium, and 1.3 for the low level. Sixteen percent of the animals in the high level had clinically diagnosed cancer compared with 9% in the medium and 3% in the low level. These results show that more animals with more severe lesions are observed in the higher than in the lower levels of feeding.

Slight, insignificant differences ($.20<P<.50$) in average amounts of

lid pigment in the present data were observed as shown by the following values: high, 33 ±6%; medium, 37 ±4%; and low, 46 ±6%. If nutrition were to have influenced these values, its effect would probably have been opposite to the trend shown by the averages; that is, a high level of feeding would likely have been associated with a high degree of pigment. Koger and Mankin (1952) observed that cows scored darker in body color in good years than in droughty ones; and Stanley (1958) noted that calves from younger dams and thus lighter milkers tended to be lighter in body color than calves from older and heavier milking dams. It seems unlikely, therefore, that the differences in feeding are responsible for the observed trend in pigment. It might be added that no attention was given to lid pigment at the time the animals were assigned to their respective feeding levels. The trend in lid pigment, however small and though ascribable to chance, is still in the direction to have accounted for some of the observed differences in cancer eye as between levels of feeding, and therefore, should

TABLE 2. THE AVERAGE NUMBER OF AFFECTED SITES ON THE EYEBALL AND LIDS PER AGE AND FEEDING LEVEL

Winter feeding level	Source of lesions	Age (years)							Average
		6	6½	7	7½	8	8½	9	
Low	Eyeball	0.21	0.36	0.43	0.50	0.54	0.68	0.64	0.48
	Lids	.29	.25	.29	.39	.46	.50	.43	.37
Medium	Eyeball	.30	.40	.51	.68	.85	.74	1.02	.64
	Lids	.30	.38	.49	.72	.66	.72	.77	.58
High	Eyeball	.29	.42	.62	.88	.92	1.12	1.04	.76
	Lids	.83	.83	.88	.96	1.00	1.17	1.08	.98

be controlled or eliminated as much as possible. Previous studies have shown that circumocular pigment has a significant inhibitory effect on lid lesions, and little or no effect on lesions developing on the eyeball (Guilbert *et al.*, 1948; Bonsma, 1949; Anderson *et al.*, 1957; Anderson, 1959). Lid pigment may be positively related to pigment at the corneoscleral junction, but this latter pigment is not significantly related to the development of lesions on the eyeball, the simple correlations between these traits in the same and opposite eyes being of the order, r=—.10 to —.15 (unpublished data). In the light of these results, the relationship between cancer eye and feeding level was evaluated separately for lesions on the lids and lesions on the eyeball in order to minimize the effects of pigment on the latter group of lesions. Eyeball lesions are the most prevalent kind of lesion, being 2 to 3 times more frequent than lid lesions. Henceforth, lid lesions shall refer to those on the lids and caruncle, and eyeball lesions to those on the eyeball and nictitating membrane. (The latter is a wholly unpigmented structure).

Table 2 and figure 2 show separately the results for these two groups of lesions. The average number of sites affected by cancer and its benign

precursor lesions was computed for each age, feeding level, and type of lesion. These were then plotted, as shown in figure 2, to which linear regressions were fitted as before.

For lesions on the eyeball, table 2 and figure 2 show that the average number of affected sites at each age after 6 years is larger in the higher

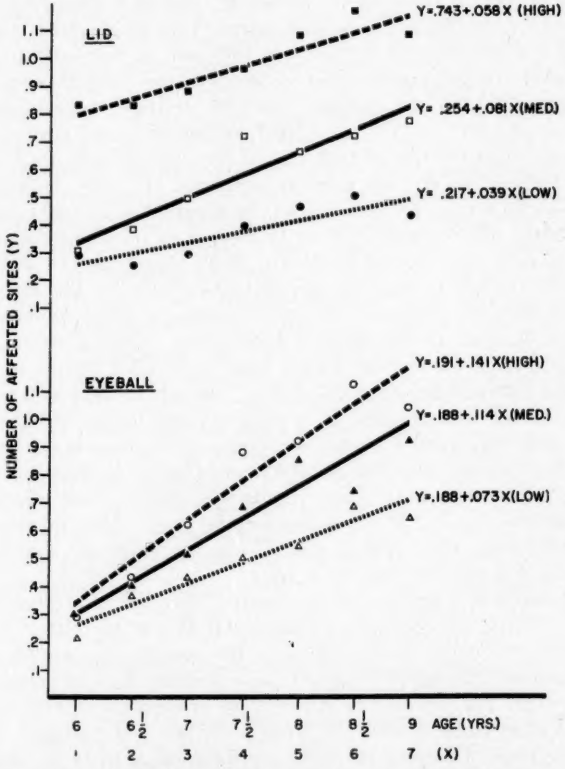

Figure 2. Number of sites on the lids and eyeball affected by lesions as related to feeding level and to age.

than in the lower feeding levels. The average over all ages is 0.76 for the high level, 0.64 for the medium, and 0.48 for the low level. The rates of increase in number of affected sites on the eyeball with each six-month increment in age are shown by the regression coefficients in each equation in figure 2. The rate of 0.14 for the high level is significantly higher ($P<.05$) than the 0.07 for the low, and so also is the 0.11 for the medium level. The rate for the high level is higher than that for the medium level,

though not significantly so. The vertical intercepts of the lines at age 5½ are very close, ranging from 0.188 to 0.191 and indicating that effects of differences in feeding on eyeball lesions become manifest after 6 years of age. It is apparent from these results that there is an association between feeding level and cancer eye when the effects of pigment have been removed for the most part.

Similar results are observed for lid lesions, though it should be recalled that differences in pigment may be involved. Very pronounced differences in cancer eye are observed at each age and over all ages with respect to feeding level. The average number of affected sites over all ages is 0.98 for the high, 0.58 for the medium, and 0.37 for the low level. The rates of increase of 0.06 and 0.08 are higher for the high and medium levels, respectively, than the rate of 0.04 for the low, though only the difference between the medium and low levels is significant ($P<.05$). Differences in lid lesions with respect to feeding level are apparent at an early age.

The results also indicate that, with respect to lid lesions, animals in the low level group required about 1½ years longer, on the average, to develop an average number of affected sites similar to the number for animals in the medium level, and never developed as many as those in the high level. Animals in the medium level group required about 3 years longer to develop the number in the high level. With regard to eyeball lesions, the intervals are generally shorter, animals in the low level group requiring almost an extra year to develop as many lesions as those in the medium level, and about 1¼ years to develop the number in the high. The medium level animals required about 6 months longer to reach the number of lesions in the high level. These results thus indicate that lesions occur earlier, on the average, at the higher feeding levels. Also, lid lesions are manifested earlier than eyeball lesions, but the latter are slightly more prevalent and show faster rates of increase.

Discussion. The manifestation of susceptibility seems to depend upon a combination of genetic and environmental factors in relation to some threshold above which cancer ensues. In the present case, a high level of winter nutrition apparently increased the probability that an animal would develop cancer eye, by moving it nearer to or even above this threshold as compared to where it would be if on lower levels of nutrition. Perhaps the higher level of feeding increases physiological activity so that these animals reach an older physiological age at a lower chronological age than animals on lower levels. The survival rates, which are now (November, 1959) 56% for the high level animals compared with rates of 63 and 90% for the medium and low levels, respectively, add credence to this possibility.

That an association should exist between nutrition and cancer is not wholly surprising since such an association has been known to exist in laboratory animals. In general, (and in accordance with present findings)

high supplements of certain dietary components tend to increase incidence, while restrictions decrease incidence and delay age at onset. The response is dependent upon the level of the particular dietary component being investigated, nature of the diet, type of tumor, potency of the carcinogen if one is involved, duration of the experiment, and type of experimental animal (See Greenstein, 1954; Tannenbaum and Silverstone, 1957, for reviews on the subject).

Additional evidence in support of present findings also comes from laboratory animals where certain genes have been shown to increase body weight and cancer susceptibility. Little (1934) reported that obese yellow mice ($A^y a$) were heavier and larger and reached tumor age earlier than non-yellow litter mates, though the latter had a higher incidence of spontaneous mammary cancer (39% vs. 65%). This was ascribed to yellow mice passing through the tumor period at a faster rate than non-yellows, thereby affording a shorter period of mammary tissue stimulation by endocrines. The non-yellows required a longer period to attain tumor age and were in that age longer, thereby affording a longer period for tumor development. Heston (1942) reported that the A^y gene increased susceptibility to pulmonary tumors even when the gene was from a resistant parent strain. He suggested that the physiological processes through which this gene increased body weight might also be responsible for increased susceptibility. Similar findings were reported for the A^y gene on spontaneous pulmonary tumors (Heston and Deringer, 1947). Other genes in mice, namely hairless (Heston and Deringer, 1949; 1951), fused (Deringer and Heston, 1955) flexed-tail, waved-*2* and shaker-*2* (Heston *et al.*, 1952) also influenced susceptibility. In each instance, the normal segregants were generally heavier and more susceptible to pulmonary tumors than the mutants. The physiological processes whereby body weight and susceptibility were both increased were ascribed to the effects of the individual genes themselves (with the exception of waved-*2*) and not to linkage of each of these with other genes having an influence on susceptibility. The association between the waved-*2* gene and susceptibility was interpreted as possibly the result of linkage between waved-*2* and shaker-*2*. More recently, Vlahakis and Heston (1959) showed that recessive obese mice had fewer induced pulmonary tumors than non-obese mice. This result appears contrary to previous findings; however, apparently it is not, since the obese mice were actually smaller than non-obese mice with respect to certain skeletal and muscular measurements. These workers suggested that susceptibility to pulmonary tumors is correlated more with normal growth of the skeletal and muscular systems than with body weight, when the latter consists largely of adipose tissue. It appears reasonable, therefore, that the higher level of feeding in the present case could enhance physiological rates of activity, thereby producing an effect which appears similar to the effect on cancer susceptibility in laboratory animals.

Summary

An experiment is described wherein each of 105 cows was exposed to one of three levels of winter feeding from November to April for 9 consecutive years. The present report covers the period from 1954 to 1957 when they were at ages 6 to 9, and during which observations of cancer eye were made at six-month intervals. Differences in level of nutrition affected cancer eye importantly. The higher level of feeding increased the average number of sites on the eyes affected by lesions and their rate of increase with age, increased the number of affected animals, and increased the stage of pathogenesis of the lesions. Moreover, the survival rate of animals on the high level was lower than that on the medium and low feeding levels. Possibly the higher nutritional level hastens the aging process so that the animals on such regimes reach an older physiological age at a younger chronological age than animals on lower feeding levels. Lesions on the lids apparently occur earlier than those on the eyeball, though the latter are more prevalent and show faster rates of increase with age.

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THE EFFECT OF OLEANDOMYCIN ON THE PERFORMANCE OF THE YOUNG GROWING PIG [1]

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SOBIN *et al.* (1954) have shown that oleandomycin, an antibiotic produced by a strain of *Streptomyces antibioticus,* is particularly active against gram positive bacteria. Sherman and Donovan (1958) and Stephenson *et al.* (1958) reported a growth response from oleandomycin when fed to chicks. Carlson (1958) reported an improvement in egg production and feed efficiency when the ration contained 5 mg. of oleandomycin per pound of feed.

Magruder *et al.* (1958) reported an improved growth rate and to a lesser extent an improvement in feed conversion for both the young pig and the growing-finishing pig when varying levels of oleandomycin were added to a basal ration. These workers reported a greater response of both the young pig and the growing-finishing pig to oxytetracycline in combination with oleandomycin than could be ascribed to the additive effects of the two antibiotics.

The experiments reported herein were conducted to study further the effect of oleandomycin on growth rate and feed conversion by the young growing pig.

Procedure

Experiment I. Forty crossbred pigs averaging 9.4 lb. in body weight and 13 days of age were randomly allotted from outcome groups of littermates to five levels (0, 1.25, 2.5 and 10 mg./pound of feed) of oleandomycin. Two replicates of four pigs per pen were fed each ration. Free access to feed and water was provided for a four-week experimental period.

Experiment II. Seventy-two crossbred pigs averaging 29.3 lb. in body weight and 50.6 days of age were randomly allotted from outcome groups of littermates to four levels (0, 2.5, 5 and 10 mg./pound of feed) of oleandomycin. Three replicates of six pigs per pen were fed each ration. The pigs were maintained in dirt lots with free access to feed and water for a 40-day experimental period.

The basal rations are presented in table 1. In each experiment the pen of pigs was considered the experimental unit and treated accordingly in the statistical analysis.

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[2] The authors gratefully acknowledge Chas. Pfizer & Co., Terre Haute, Ind., for Grants-in-aid and materials which partially supported this research.

[3] Department of Animal Husbandry.

TABLE 1. PERCENTAGE COMPOSITION OF BASAL RATIONS

Ingredient	Exp. I	Exp. II
Ground yellow corn	35.60	78.55
Sovent soybean oil meal (50% protein)	20.65	17.00
Ground oat groats	20.00	.....
Dried whey (70% lactose)	15.00	.....
Stabilized lard	2.00	.....
Condensed fish solubles	2.50	.....
Pepsin (1:3000)	0.25	.....
Vitamin premix	2.00[a]	2.00[b]
Calcium carbonate	0.70	0.55
Dicalcium phosphate	0.60	1.30
Iodized salt	0.50	0.50
Trace mineral premix[c]	0.20	0.10
	100.00	100.00

[a] Vitamin premix supplied the following supplemental vitamins: 2700 I.U. vitamin A, 500 I.U. vitamin D_2, 1.5 mg. riboflavin, 1.6 mg. pantothenic acid, 15.2 mg. niacin, 20 mcg. vitamin B_{12} and 20 mcg. folic acid per pound of ration.

[b] Vitamin premix supplied the following supplemental vitamins: 1200 I.U. vitamin A, 400 I.U. vitamin D_2, 1.9 mg. riboflavin, 3.0 mg. pantothenic acid, 11.3 mg. niacin and 10 mcg. vitamin B_{12} per pound of ration.

[c] Trace mineral premix, 0.1%, supplied the following in ppm.: iron 70.4, copper 4.8, cobalt 1.6, zinc 81.6 and manganese 56.8.

Results and Discussion

Experiment I. The data for daily rate of gain and feed required per pound of gain are presented in table 2. Each level of oleandomycin tested resulted in an improvement in both rate of gain and feed conversion when compared to the performance on the basal ration. Gains improved linearly

TABLE 2. SUMMARY OF GAINS AND FEED REQUIRED PER POUND OF GAIN

Oleandomycin level, mg. per lb.	0	1.25	2.5	5.0	10.0
Baby pigs (Exp. I)					
Av. initial wt., lb.	9.44	9.21	9.02	9.56	9.59
Av. final wt., lb.	19.62	22.31	22.19	23.56	24.19
Av. daily gain, lb.[a]	0.36	0.47	0.47	0.50	0.52
Feed per gain, lb.[b]	2.02	1.73	1.62	1.69	1.62
Growing pigs (Exp. II)					
Av. initial wt., lb.	29.2	....	29.4	29.1	29.6
Av. final wt., lb.	75.8[c]	....	79.7	79.2[d]	79.0[e]
Av. daily gain, lb.	1.16	....	1.26	1.24	1.24
Feed per gain, lb.[f]	2.82	....	2.60	2.52	2.63

[a] Linear regression significant, P=0.10 or less.

[b] Linear regression significant, P=0.05 or less.

[c] Two pigs were removed from this treatment. Necropsy examination revealed an umbilical abscess on one animal.

[d] One pig was removed from this treatment. Postmortem examination revealed no gross lesions nor the presence of pathogenic bacteria.

[e] Two pigs were removed from this treatment. One pig had a viral type pneumonia and one revealed lesions of a bacterial septicemia. *Salmonella sp.* was isolated from the latter animal.

[f] Quadratic regression significant, P=0.10 or less.

(P=0.10 or less) with increasing levels of the antibiotic. Likewise, statistical analysis of the feed/gain data showed a linear improvement with increasing levels of oleandomycin. However, for each criterion (gains and feed/gain) there was a tendency for the response to plateau at the lower levels (1.25 to 2.5 mg./lb.) of supplementation.

Experiment II. The data for daily rates of gain and feed required per pound gain are presented in table 2. Here again the feeding of oleandomycin resulted in an apparent improvement in both rate of gain and feed conversion. The differences in rate of gain were not statistically significant. However, the quadratic regression of feed/gain on increasing oleandomycin levels was significant at the probability level of 0.10 or less, the most efficient feed conversion being observed at the level of 5 mg. per pound of feed.

Summary

Two experiments involving 40 baby pigs and 72 growing pigs initially averaging 9.4 lb. and 29.3 lb. body weight, respectively, were conducted to study the effect of varying levels of oleandomycin on growth rate and feed conversion. With baby pigs, maximum response was observed at the highest level fed (10 mg./lb. of feed), which resulted in a 44% improvement in growth rate and a 25% improvement in feed conversion as compared to the pigs fed the control diet. The optimum level for the growing pig (5 mg./lb. of feed) resulted in a 6.9% improvement in rate of gain and 7.2% improvement in feed conversion.

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A TECHNIQUE FOR MEASURING THE CROSS-SECTIONAL AXES OF THE LONGISSIMUS DORSI MUSCLE AND FAT DEPTH IN LAMBS [1, 2]

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STUDIES by Levine and Hunter (1956) and the Institute for Motivational Research, Inc. (1956) indicate that lamb consumers prefer meatiness in lamb cuts, and find excess fat wasteful and unpalatable. These preferences should be considered in lamb production and evaluation of lamb carcasses. However, before genetic improvement can be made in lamb muscling characteristics, it is necessary to determine in the live animal the factors that indicate muscling in the carcass. Lamb breeders need methods, not influenced by differences in fatness, to identify superior muscling in the breeding animal. Selection for such muscling is difficult because slaughter is necessary for the most accurate appraisal. The rather low reproductive rate and relatively long generation interval in sheep limit the practicability of slaughter-testing sibs or progeny.

Objective techniques for determining carcass characteristics in hogs have been studied. The live probe has been evaluated in hogs by Hazel and Kline (1952), De Pape and Whatley (1956) and Hetzer *et al.* (1956), and it is a reliable indicator of backfat thickness, percentage of lean cuts, and carcass leanness. Pearson *et al.* (1957) found little difference between the accuracy of the probe and the lean-meter for evaluating hogs. The live probe was more accurate than the lean-meter in predicting loin eye area and fat trim. Holland and Hazel (1958) found the probe to be highly accurate in appraising leanness in hogs as measured by percent lean cuts. However, a similar probe of muscle thickness over the supraspinous fossa and over the illium was not so closely related to lean cut percentages.

This study was initiated to determine the accuracy of a technique designed to measure muscling and depth of fat in live lambs.

Experimental Procedure

Eighty-six lambs were randomly chosen from two separate feeding trials for comparing live lamb muscling measurements with carcass measurements. The 46 lambs in the first trial were Down crossbreds of various types which produced carcasses grading U. S. Choice and U. S. Prime. In the second trial, the 40 lambs were whiteface crossbreds and their car-

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casses ranged in grade from U. S. Utility to U. S. Choice. Live weights ranged from 72 to 109 lb. in trial 1 and from 79 to 117 lb. in trial 2.

The lambs were shorn immediately before measurement to facilitate palpation of anatomical reference points. The transverse process of the second lumbar vertebra was selected as the reference point for width and depth estimates of the longissimus dorsi muscle since (1) a relatively flat surface was needed to obtain accurately the depth probe, (2) a width measurement close to the 12th and 13th rib was desired, (3) the first lumbar transverse processes are short and do not approximate the lateral extent of the longissimus dorsi muscle as closely as those of the second, and (4) the second transverse processes are more easily palpated than the first.

Measurements employed to evaluate muscling in live lambs were as follows: width of the longissimus dorsi muscle was estimated as half the distance between the lateral extremities of the transverse processes of the second lumbar vertebra. This distance was measured with metal calipers and recorded to the nearest 1/10 in. Depth of the longissimus dorsi muscle was estimated with an 18 gauge probing needle, inserted through a cork, at the second lumbar transverse processes; these and the mid-line were easily determined by palpation. Skill in palpating the transverse processes was developed by injecting food dyes at the sites palpated and observing the location of the dye in the dissected carcasses of several trial lambs prior to conducting this study.

The lambs were restrained so they were standing squarely on their legs with the top-line level. The area over the transverse process was shaved and a small dot of ink was placed on the skin one inch laterally to the right of the mid-line. A solution of 70% alcohol was applied and a small incision was made in the skin with a surgical scalpel at the inked site. The probing needle penetrated the fat with little resistance; however, it met marked resistance from the lumbo-dorsal fascia covering the longissimus dorsi muscle. At this point the cork was pressed firmly against the skin. The needle was withdrawn and the distance from the point of the needle to the cork was recorded as skin thickness plus fat depth. The distance was measured on a steel rule to the nearest 1/10 in. The needle was then reinserted and pressure was applied until it passed through the fascia and penetrated the longissimus dorsi muscle to the dorsal surface of the transverse process of the second lumbar vertebra. The cork was again pressed firmly against the skin and the needle withdrawn. The difference between depth of skin plus fat and total depth, measured to the nearest 1/10 in. was recorded as the estimate of cross-sectional depth of the longissimus dorsi muscle.

Only five carcasses, among those produced by the first 46 lambs probed, had any indication of the probe site. These carcasses showed a very small mark, apparently resulting from the rupture of a small superficial blood vessel. When carefully done, bleeding was negligible and the probe of

the longissimus dorsi muscle caused less distress to the lambs than the tiny incision made in the skin with the scalpel.

The estimate of cross-sectional area of the longissimus dorsi muscle was obtained by multiplying the estimated width by the probe depth.

The carcasses were separated into fore and hind saddles between the 12th and 13th rib, and the longissimus dorsi muscle and fat depth were traced at the 12th rib.

Cross-sectional width (length axis) and depth (width axis) of the longissimus dorsi muscle were measured from tracings of the muscle with a small metal ruler and recorded to the nearest 1/10 in. Cross-sectional area of the longissimus dorsi muscle was determined by the polar planimeter from muscle tracings. Fat depth at the 12th rib was measured in millimeters in accordance with the procedure outlined by the lamb evaluation committee of the Reciprocal Meats Conference (1953). Carcass grade was recorded to the nearest one third of a grade by an official of the USDA Federal Grading Service.

Accuracy of the live lamb estimates was determined by correlating the estimates with actual carcass measurements. Simple and partial correlations (independent of live weight) were calculated as described by Snedecor (1946).

Results and Discussion

To determine the maximum accuracy of width and depth measurements in estimating cross-sectional area of the longissimus dorsi muscle in live lambs, a correlation coefficient was calculated between actual area (planimeter reading) and area estimated from the product of actual width x depth axes of the longissimus dorsi muscle in the carcass. The simple correlation between estimated and actual areas was 0.83 in the initial trial. A high correlation was anticipated since muscle depth and width axes are functions of cross-sectional area. The coefficient of determination, 0.69, indicates considerable variation in muscle area even among muscles with identical axes measurements.

Partial correlation coefficients between carcass characteristics and estimates of cross-sectional dimensions of the longissimus dorsi muscle and fat depth at the 12th rib in live lambs for trials 1 and 2 are shown in table 1.

The estimate of cross-sectional width of the longissimus dorsi muscle, as determined on the live lamb by halving the distance between the lateral extremities of the transverse processes of the second lumbar vertebra was not a reliable indicator of the actual cross-sectional width of the muscle in the carcass. The partial correlation coefficients 0.15 and 0.30 for the two trials were nonsignificant. However, the correlation 0.30, for lambs in trial 2 approached the 0.05 level of significance. The lambs in trial 1 possessed more external fat than those in trial 2. The lower correlation obtained in trial 1 may be attributed to differences in fatness since meas-

urements of width of the transverse processes were less repeatable on fatter lambs due to difficulty in palpating and measuring the processes.

It was anticipated that the lateral extent of the transverse processes and of the longissimus dorsi muscle may be rather closely related because the lumbo-dorsal fascia closely invests the longissimus dorsi muscle. The fascia is attached medially to the supraspinous ligament and supraspinous processes with the lateral edge of the fascias's deep layer curving under the longissimus dorsi muscle and inserting at the lateral extremities of

TABLE 1. PARTIAL CORRELATION COEFFICIENTS BETWEEN CARCASS MEASUREMENTS AND ESTIMATES OF CROSS-SECTIONAL DIMENSIONS OF THE LONGISSIMUS DORSI MUSCLE AND FAT ESTIMATES ON THE LIVE LAMB

Actual cross-sectional measurements of the Longissimus dorsi muscle	Live lamb estimates			
	Long. dorsi m. width	Long dorsi m. depth	Long. dorsi m. area	Lumbar fat depth
Width				
T1	0.15	....	....	....
T2	0.30	....	....	....
Depth				
T1	—.22	0.43**	....	....
T2	0.16	0.62**	....	....
Area				
T1	—.01	0.56**	0.55**	....
T2	0.42**	0.59**	0.69**	....
Fat depth at 12th rib				
T1	—.18	0.03	—.12	0.57**
T2	—.19	—.17	—.12	0.82**
Carcass grade				
T1	—.05	—.08	—.09	0.51**
T2	....	....	....	0.40**

T1 and T2=trials 1 and 2.
** $P<0.01$.

the transverse processes. In addition, the muscle's origin and insertion are the supraspinous and the transverse processes, respectively. In cross-sectional cuts of carcasses, the fascia-covered muscle extends slightly farther laterally than the extremities of the processes but the fascia holds the lateral extent of the muscle in close proximity to the ends of the processes.

The estimates of cross-sectional depth of the longissimus dorsi muscle (probe technique) were highly significantly correlated, 0.43 and 0.62, with cross-sectional depth of the muscle in the carcasses of trials 1 and 2, respectively. Variation in fat depth probably accounts for the difference between the correlations. These correlations agree rather closely with those reported by Stouffer *et al.* (1958). They probed the longissimus dorsi

muscle plus fat at the last rib and their probe estimate was significantly correlated with actual depth of the muscle, 0.58.

The probe estimate of the longissimus dorsi muscle depth was also significantly correlated at the 0.01 level with the cross-sectional area of the muscle in the carcasses of lambs in both trials. The partial correlation coefficients were, 0.56 and 0.59, for trials 1 and 2, respectively. These correlations were slightly higher than the 0.42 published by Stouffer *et al.* (1958) for muscle plus fat probe with cross-sectional area of the longissimus dorsi muscle.

In trial 1, probe depth alone was just as highly correlated with actual cross-sectional area of the longissimus dorsi muscle as the estimate of area based on depth and width measurements. These correlations were 0.56 and 0.55, respectively. However, for lambs in trial 2, the estimate of cross-sectional area was more highly correlated, 0.69, than the depth estimate, 0.59, with actual area of the muscle. The product of the width and depth estimates resulted in very little increase in accuracy for predicting cross-sectional area of the longissimus dorsi muscle over that of the depth estimate alone.

The average estimated area of the longissimus dorsi muscle in trial 1 was 2.42 sq. in., while the average area in the carcass was 2.07 sq. in. The estimate was correlated, 0.55, with actual area and the regression of estimated on actual area was 0.88. In trial 2 the average estimate was 2.44 sq. in. and area in the carcass was 2.03 sq. in. The estimate was correlated, 0.69, with actual area and the regression of the estimate on the actual area was 0.82.

The coefficients of determination (r^2) between estimated and actual areas of the longissimus dorsi muscle were 0.30 and 0.48 for the two trials, respectively. Orme *et al.* (1959) reported that width of the body of the lumbar vertebra and width of the vertical processes in cattle, as determined by radiographic measurements, accounted for 22 and 20%, respectively, of the variation in rib eye area.

Considerable unaccounted for variation existed between estimated and actual measurements of area; however, this is not surprising since the coefficient of determination obtained by squaring the correlation (0.83) between actual area of the longissimus dorsi muscle and area determined from the product of the axes measurements of the actual muscle was only 0.69. These data indicate that the maximum correlation one could expect is 0.83 and this is possible only if one can correctly estimate the actual axes of the muscle. However, the accuracy of estimating the axes is influenced by degree of fatness and skin and bone thickness.

Partial correlation coefficients (with live weight held constant) between actual carcass characteristics are shown in table 2. Nonsignificant negative correlations between width and depth (from muscle tracings) of the longissimus dorsi muscle were —.13 and —.01, respectively. The correlation between estimated width and actual depth of the longissimus dorsi muscle

was nonsignificant and negative in the first trial (—.22). In the second trial, the correlation was nonsignificant but positive (0.16). Actual width of the longissimus dorsi muscle was significantly correlated at the 0.01 level with actual cross-sectional area of the muscle in the carcasses from lambs in trial 1 (0.49), but was nonsignificant (0.16) in trial 2. Estimated width of the muscle was more highly correlated with actual area in trial 2 (0.42). Width of the muscle was negatively correlated (significant at the 0.05 level) with fat depth at the 12th rib (—.32). Estimate of muscle width was negatively correlated with fat depth in both trials, 0.18 and 0.19. Actual width of the longissimus dorsi muscle was correlated with

TABLE 2. PARTIAL CORRELATIONS BETWEEN ACTUAL CARCASS MEASUREMENTS

Actual cross-sectional measurements of the Longissimus dorsi muscle	Long. dorsi m. width	Long dorsi m. depth	Long. dorsi m. area	Lumbar fat depth
Depth				
T1	—.13	....	....	....
T2	—.01	....	....	....
Area				
T1	0.29*	0.74**	....	....
T2	0.16	0.68**	....	....
Fat depth at 12th rib				
T1	—.32*	—.13	—.31*	....
T2	....	....	—.11	....
Carcass grade				
T1	—.29*	0.29*	—.02	0.36*
T2	—.58**	0.29	—.19	0.61**

T1 and T2=trials 1 and 2.
* $P<0.05$.
** $P<0.01$.

carcass grade, —.29 ($P<0.05$) and —.58 ($P<0.01$), in trials 1 and 2, respectively. The live estimate of muscle width was negatively related (—.05) to carcass grade.

Depth of the longissimus dorsi muscle was correlated ($P<0.01$) with cross-sectional area of the muscle, 0.74 and 0.68 in trials 1 and 2, respectively. The correlations between estimate of depth and actual area were 0.56 and 0.59 in the two trials. The correlation between actual depth of the longissimus dorsi muscle and carcass grade approached significance, 0.29 and 0.29; however, live estimate of depth of the muscle was not so closely related (—.08) to carcass grade.

Cross-sectional area of the longissimus dorsi muscle was significantly correlated with fat depth at the 12th rib, —.31 and —.11 in trials 1 and 2, respectively. Live lamb estimates of muscle area were also negatively correlated with fat depth at the twelfth rib, —.12 and —.12. Actual and

estimated areas of the longissimus dorsi muscle were slightly negatively correlated with carcass grade. In trial 1 the correlation of actual and live lamb estimates of fat depth with carcass grade were significant ($P<0.01$), 0.36 and 0.61, respectively. In trial 2 corresponding correlations, 0.40 and 0.50, respectively, were also significant ($P<0.01$).

Summary

A technique for measuring depth and width of the longissimus dorsi muscle was studied on 86 lambs randomly chosen from two separate feeding trials. Depth of the longissimus dorsi was estimated by needle probe over the right transverse process of the second lumbar vertebra. Width of the muscle was estimated as the width of the transverse processes of the second lumbar vertebra. The product of width and depth estimates was recorded as estimated cross-sectional area of the longissimus dorsi muscle.

Depth probe was significantly correlated at the 0.01 level with actual cross-sectional depth of the muscle for carcasses of lambs from trials 1 and 2, 0.43 and 0.63, respectively. The depth probe estimate was highly significantly correlated, 0.56 and 0.59, with the cross-sectional area of the muscle in both trials. Estimated width of the muscle was not a reliable indicator of actual cross-sectional width. Estimated cross-sectional area of the longissimus dorsi muscle was significantly correlated at the 0.01 level with actual area of the muscle, 0.55 and 0.69 in trials 1 and 2, respectively.

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A COMPARISON OF THE GROWTH HORMONE CONTENT OF THE PITUITARY GLANDS FROM DWARF AND NORMAL BEEF CALVES

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THE hereditary nature of drarfism in beef cattle appears to be reasonably well established as being conditioned by a single pair of homozygous, recessive genes (Baker *et al.*, 1950, 1951; Gregory *et al.*, 1951, 1953; Lush and Hazel, 1952; Pahnish *et al.*, 1955; and others). However, no one has offered a satisfactory explanation of the abnormal physiological action of the responsible gene. Opinions have varied widely among people interested in this problem as to its cause, and, likewise, conflicting solutions have been proposed. Many people have postulated an endocrine malfunction. Carroll *et al.* (1951) reported that dwarf calves of the Hereford breed were grossly deficient in thyrotropic hormone content of the pituitary. However, studies reported by Marlowe (1954), Marlowe and Chambers (1954), Fransen and Andrews (1954), and Crenshaw *et al.* (1957) would indicate that there is no deficiency of thyrotropic, ACTH, or gonadotropic hormones in the pituitaries of dwarf calves, nor is there any deficiency in thyroid activity.

The primary limiting factor in dwarf calves appears to be abnormal skeletal development (Gregory *et al.*, 1953; Buchanan *et al.*, 1956; Julian *et al.*, 1956), and it has been shown that hypophyseal growth hormone has a direct influence on bone growth (Simpson *et al.*, 1950; Asling *et al.*, 1955). Since it is known that dwarfism in other species results from the absence, or a deficiency, of growth hormone (Smith and McDowell, 1930, 1931; Friedgood, 1946; Freeman, 1950), it seemed reasonable to suspect that dwarfism in beef cattle might be the result of an insufficient amount of this hormone. The purpose of this study was to investigate that possibility.

Materials and Methods

Pituitary glands were collected from a large number of dwarf and normal beef calves to be assayed for growth hormone (somatotropin) content. No attempt was made to determine the amount quantitatively. Rather, an attempt was made to compare by the tibia test glandular material obtained from dwarf and normal calves. A selected, weighed amount of powdered glandular material was taken from each gland, suspended in a given amount

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of sterile, physiological saline and injected into hypophysectomized, immature, female rats. They had been hypophysectomized when 26 to 28 days of age. All rats were fairly uniform in weight within trials. Injections were started approximately 14 days later. All rats were obtained from Hormone Assay Laboratories, Incorporated, Chicago. The injection period was 4 days. All rats were sacrificed on the fifth day approximately 24 hours after the last injection. The tibia test was used as the measure of response to growth hormone, procedures being essentially those of Greenspan *et al.* (1950).

The dwarf and normal calves from which the glands were obtained for each trial were reasonably comparable as to breed, sex, and age. They varied somewhat, however, and an attempt was made to estimate and eliminate those differences in the analysis of the data.

Four assays were conducted in these comparisons. The materials and procedures for each assay are outlined below. Two rats were housed per cage and allotted to treatments at random.

Trial 1. Pituitary glands were collected from 15 dwarf and 15 normal calves of the Hereford, Angus and Shorthorn breeds. In each group there were 10 Herefords, four Angus, and one Shorthorn. Of the Herefords, two were females and eight were males in the dwarf group and four were females and six were males in the normal group. Of the Angus, three females and one male were in each group. The Shorthorn in each group was a male. Most of the calves were between 4 and 6 months of age.

The whole glands were trimmed, weighed, placed in acetone, and stored in a refrigerator until ready for use. Just prior to assay, the glands were removed from the acetone, the connective tissue capsules removed, and all glandular material macerated in a small mortar to a fine powder. The powder was weighed and 40 mg. from each gland was suspended in sterile, physiological saline to make 5 ml. of the suspension. This was stored in a small vial. Material from each vial was then injected into two rats at the rate of 0.5 ml. daily (4 mg. powder per rat per day).

Trial 2. Glands were compared from five dwarf and five normal calves all of the Hereford breed. There were four females and one male in each group. The dwarf animals ranged in age from 6 to 12 months and the normals from 6 to 8 months. The glands were removed immediately following slaughter, trimmed, weighed, placed in acetone and stored in a refrigerator until ready for use. For the assay, they were removed from the acetone and the anterior lobe was removed, powdered and suspended in sterile, physiological saline. Material from each gland was injected into eight rats on two levels (400 and 800 micrograms). Each rat was injected twice daily with 0.2 ml. per injection. One composite sample of all normal glands and one of all dwarf glands were injected into an additional eight rats at each level.

Trial 3. Pituitary glands from three normal and three dwarf calves were compared. The dwarf calves were heifers and included two Angus and

one Hereford. The normal calves were Herefords, two heifers and one steer. Immediately after removal of the pituitary gland from the calf the anterior lobe was dissected out, split open and pressed between two heavy glass plates. It was dried over calcium chloride in a desiccator. The finely powdered material from each gland was suspended in sterile, physiological saline and injected into eight rats at the rate of 400 micrograms per rat daily. Injections of 0.2 ml. of suspension were given twice daily.

Trial 4. Pituitary glands were compared from seven dwarf and seven normal calves. All calves were Herefords, five females and two males in each group. These animals were 4 to 5 months old. All glands were removed from the animals at the slaughtering plant, placed in individual containers, and stored in ice for several hours while being transported to Blacksburg. On arrival they were stored at —10° C. until assayed. For assay, the glands were dried under vacuum at a very low pressure while still frozen. When dry they were powdered and suspended individually in sterile, physiological saline for injection. Material from each gland was injected daily into six rats at the rate of 100 micrograms of material suspended in 0.1 cc. saline.

Results and Discussion

Even though an effort was made to obtain pituitary glands from dwarf and normal beef calves that were comparable in age, sex, and breed, this was not always possible. Consequently, in the analysis of the data for trials 1, 2, and 3, the conventional least squares method was used in an attempt to estimate these and other effects, such as reader differences, on the width of the epiphyseal cartilage of the tibia. The unadjusted means by trial and treatment are shown in table 1.

It was assumed that there were no interactions so the model could be written:

$$y_{ijklm}=\mu+b_i+s_j+t_k+r_l+e_{ijklm}$$

where b_i is the effect of breed of calf, s_j is the effect of sex of calf, t_k is the effect of type of material injected, r_l is the effect of reader on the measurements, and e_{ijklm} is the experimental error. The t-test of individual mean differences was made, using the formula:

$$t=\frac{b_1-b_2}{\sqrt{S^2(C_{ii}+C_{jj}-2C_{ij}}}$$

where C_{ii}, C_{jj} and C_{ij} are the elements of the C matrix, in those instances where direct F-test comparisons were not made in the least squares analysis.

Trial 1. Both negative and positive controls were used in this trial in order to evaluate properly the responsiveness of the assay animals to the hormone.

Least squares estimates of the various effects studied are shown in

table 2. Values shown in the three right hand columns were adjusted for differences in final rat weight. The analysis of variance for regression of final rat weight on cartilage width was highly significant; however, such an adjustment is probably unsound biologically since the material that stimulated an increase in cartilage width also stimulated general body growth to a lesser degree. All values are relative to the selected base in each classification; i.e., to the level of reader 1, saline injected controls, and bull calves of the Hereford breed.

The analysis indicated that rats receiving powder from pituitary glands out of Angus calves had significantly wider epiphyseal cartilages than those receiving powder from pituitaries out of Hereford calves. Sex of calf had no significant effect on cartilage width. All treatment groups had sig-

TABLE 1. OBSERVATIONS AND UNADJUSTED MEANS OF CARTILAGE WIDTH IN DIFFERENT TRIALS

	No. of observations in trial				Cartilage width (micra) in trial			
Item	1	2	3	4	1	2	3	4
Saline control	58	20	8	13	90.0	105.1	105.2	93.1
Dwarf gland	58	96	38	39	136.4	145.9	166.0	183.8
Normal gland	60	96	44	36	173.9	153.9	179.8	186.8

nificantly wider epiphyseal cartilages than the saline controls. Rats injected with normal calf pituitary powder had significantly wider epiphyseal cartilages than those injected with dwarf calf pituitary powder ($P<.01$). Rats injected with a purified hormone had significantly wider epiphyseal cartilages than rats injected with glandular material. In the comparison of normal calf pituitary powder with purified growth hormone, the t-value was 6.95 ($P<.01$).

Trial 2. Least squares estimates of the effects of sex of calf, type of material, level of injection, reader, and initial weight of rat on the width of the epiphyseal cartilages in this trial are shown in table 3. Adjusting for the minor differences in initial rat weight had no significant effect on cartilage width. Regardless of whether adjustment was made for initial weight of rat, there was a highly significant difference ($P<.01$) in response to injection of dwarf and normal pituitary material. In the comparison of normal with dwarf the t-values when no adjustment was made for initial rat weight and when cartilage widths were adjusted for differences in initial rat weight were 2.61 and 2.62, respectively. There was no significant difference attributable to sex of calf, but there was a highly significant difference between levels and readers. On the average, rats receiving the 800-microgram level had cartilage widths 16.77 units greater than those receiving the 400 level.

TABLE 2. LEAST SQUARES ESTIMATES OF THE EFFECTS OF BREED AND SEX OF CALF, MATERIAL INJECTED, READER, AND FINAL WEIGHT OF RAT ON THE WIDTH OF THE EPIPHYSEAL CARTILAGE OF THE TIBIA

Effects		No. of observations	No adjustment for rat wt.[a]			Adjusted for final rat wt.[a]		
			b-value[c]	Standard error	F value	b-value[c]	Standard error	F value
Breed	1.1 Angus	32	22.09	±5.72	14.92**	18.15	±4.82	14.14**
	1.2 Hereford	78	00.00	....	.....	00.00	....	.....
	1.3 Shorthorn	8	14.00	±9.21	2.32	1.97	±7.85	0.06
Sex	2.1 Bulls	72	00.00	....	.....	00.00	....	.....
	2.2 Heifers	46	—8.95	±5.34	2.81	—19.48	±4.64	17.63**
Type of material	4.1 Saline	58	00.00	....	.....	00.00	....	.....
	4.2 N. gland	60	82.21	±5.65	211.30**	57.75	±5.49	110.59**
	4.3 D. gland	58	43.11	±5.47	62.04**	31.95	±4.77	44.94**
	4.4 G.H.[b]	20	129.37	±6.76	365.78**	82.86	±7.72	115.02**
Reader	7.1 T.J.M.	98	00.00	....	.....	00.00	....	.....
	7.2 M.K.	98	—15.28	±3.49	19.08**	—15.28	±2.94	27.03**
Weight	x_2 Final	98	.....	....	.....	2.98	±0.33	78.92**
	bo	196	96.68	....	.....	127.92	....	.....

** Significant at 1% level.
[a] R^2 was 0.76 and 0.83, respectively.
[b] Purified growth hormone supplied by the Armour Laboratories, Chicago.
[c] Estimated effect on cartilage width measured in micra.

TABLE 3. LEAST SQUARES ESTIMATES OF THE EFFECTS OF SEX OF CALF, TYPE OF MATERIAL, LEVEL OF INJECTION, READER, AND INITIAL WEIGHT OF RAT ON THE WIDTH OF THE EPIPHYSEAL CARTILAGE OF THE TIBIA

Effects		No. of observations	No adjustment for rat wt.			Adjusted for initial rat wt.		
			b-value[a]	Standard error	F value	b-value[a]	Standard error	F value
Sex	2.1 Bull	32	—2.895	±4.14	0.49	—2.986	±4.24	0.50
	2.2 Heifer	128	0.000	....	.....	0.000	....	....
	2.3 Composite	32	—5.551	±4.14	1.80	—5.559	±4.15	1.80
Type of material	4.1 Saline	20	0.000	....	.....	0.000	....	....
	4.2 Normal	96	41.753	±5.46	58.31**	41.727	±5.48	57.85**
	4.3 Dwarf	96	33.855	±5.46	38.34**	33.811	±5.50	37.83**
Level	5.4 400 microgram	96	0.000	....	.....	0.000	....	....
	5.6 800 microgram	96	16.771	±3.02	30.81**	16.814	±3.06	30.27**
Reader	7.1 T.J.M.	106	0.000	....	.....	0.000	....	....
	7.2 M.K.	106	—13.457	±2.87	21.90**	—13.457	±2.88	21.80**
Rat wt.	x_i Initial	212	.....	....	.....	0.039	±0.33	0.01
	bo	212	211.878	....	.....	108.936	....	....

[a] Estimated effect on cartilage width measured in micra.
** Significant at 1% level.

TABLE 4. LEAST SQUARES ESTIMATES OF THE EFFECTS OF BREED OF CALF, KIND OF PITUITARY MATERIAL, READER, AND INITIAL WEIGHT OF RAT ON THE WIDTH OF THE EPIPHYSEAL CARTILAGE OF THE TIBIA

Effects		No. of observations	No adjustment for rat wt.[a]			Adjusted for initial rat wt.[a]		
			b-value[b]	Standard error	F value	b-value[b]	Standard error	F value
Breed	1.1 Angus	24	—9.819	±6.67	2.11	—9.228	±6.66	1.92
	1.2 Hereford	58	0.000	....	.....	0.000	....	....
Type of material	4.1 Saline	8	0.000	....	.....	0.000	....	....
	4.2 Normal	44	74.631	±7.73	93.16**	68.011	±8.29	67.35**
	4.3 Dwarf	38	67.027	±8.91	56.51**	61.535	±9.18	44.91**
Reader	7.1 T.J.M.	45	0.000	....	.....	0.000	....	....
	7.2 B.S.	45	—10.400	±4.24	6.01*	—10.400	±4.17	6.23*
Rat wt.	x_1 Initial	90	.....	....	....	0.709	±3.96	4.01*
	bo	90	110.387	....	....	56.349	....	....

[a] R^2 was 0.54 and 0.57, respectively.
[b] Estimated effect on cartilage width measured in micra.
* Significant at 5% level.
** Significant at 1% level.

Trial 3. Least squares estimates of the effects of breed of calf, kind of material used, reader, and initial weight of rat on the width of the epiphyseal cartilage of the tibia are shown in table 4. In this trial there was no significant difference attributable to breed of calf. Differences in both initial rat weight and reader had a significant influence on cartilage width. Both groups receiving injections of pituitary material had significantly wider epiphyseal cartilages than the saline control group. Differences in width of epiphyseal cartilage between groups injected with normal and dwarf pituitary material were highly significant ($P<.01$),

TABLE 5. ANALYSIS OF VARIANCE OF CARTILAGE WIDTHS IN RESPONSE TO INJECTIONS OF PITUITARY MATERIAL FROM DWARF AND NORMAL BEEF CALVES

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F values
Total	87	175175.03	.....	.....
Between treatments				
C vs. N+D	1	93948.08	93948.08	80.38**
N vs. D	1	175.10	175.10	.15
Within treatments				
Between cages within treatments	46	53762.63	1168.75	1.67
Between glands in N	6	11819.16	1969.86	2.82
Between glands in D	6	4248.23	708.04	1.01
Within glands in N	14	18551.80	1325.13	1.89
Within glands in D	14	18323.08	1308.75	1.87
Within controls	6	820.38	136.73	....
Within cages in treatments	39	27289.02	699.72	....
Within cages for N	15	13983.96	2024.73	....
Within cages for D	18	12326.70	1253.96	....
Within cages for C	6	978.36	1329.75	.....

** Significant at 1% level.

t-values being 3.89 when no adjustment was made for initial weight of rat and 3.69 when adjusted.

Trial 4. Since previous trials had indicated that cartilage width was only slightly affected by minor differences in initial weight of rats or by sex of calf, and since all glands used in this assay were out of Hereford calves, these effects were not adjusted for in this trial. The analysis of variance table is shown below as table 5.

The analysis indicated that there was a highly significant difference between treatments. However, comparisons with individual degrees of freedom showed that the difference could be attributed almost entirely to the comparison of controls vs. rats receiving injections of pituitary material. There was no significant difference between the group receiving pituitary material from dwarf calves and the group receiving pituitary material from normal calves. A further breakdown of the degrees of free-

dom within treatments indicated that there was no significant difference attributable to cages within treatments or to glands within treatments.

Three of the four trials indicated a smaller amount of growth hormone present per unit of pituitary powder from dwarf calf than from normal calf glands. There is no explanation immediately apparent for the failure of trial 4 to show a significant difference. The preparation of the pituitary powder was different and the level of injection was lower. This does not appear to be a plausible reason, however, since the average stimulation of cartilage width was greater in trial 4 than in the other trials.

In an effort to determine why there were significant differences between the groups receiving pituitary material from dwarf calves and from normal calves in trials 1, 2, and 3 but not in trial 4, a conventional least squares analysis was done, data collected in several trials (242 observations) being used to estimate such influences as preparation of material, level of injection, time of trial, and weight of rat on the width of the epiphyseal cartilage of the tibia. The estimates indicated that there was a highly significant difference between acetone-dried and air-dried material and between acetone-dried and freeze-dried material but no significant difference between air-dried and freeze-dried materials. After the cartilage widths were adjusted for differences caused by differences in initial weight of rats, the t-values were 7.18 ($P<.01$), 4.66 ($P<.01$) and 1.06, respectively. Air-dried material increased cartilage width 43.42 units and freeze-dried material 55.90 units over the acetone-dried material. The width of the epiphyseal cartilage increased as the level of injection increased from 0 to 800 micrograms, when injections were given at the 0-, 100-, 200-, 400-, and 800-level. When cartilage width was adjusted for differences in initial weight of assay animal, there was no significant difference attributed to time of trial for the four trials comparing the growth hormone potency of pituitaries from dwarf and normal calves. Adjusting for difference in initial weight of rats had a small but significant effect on the width of the epiphyseal cartilage in trial 3 and was effective in eliminating differences between trials. R^2 for this analysis was 0.78.

These findings are not in agreement with earlier findings reported by Marlowe and Chambers (1954). It is now believed that the earlier results were influenced by unfavorable conditions in the animal laboratory as indicated by infections, loss of weight, and death of many of the assay animals.

Summary

Pituitary glands from 30 dwarf and 30 normal calves were assayed for growth hormone content. A series of four assays was conducted with hypophysectomized, immature, female rats as the assay animals. Increase in width of the epiphyseal cartilage of the tibia was the measure of response.

Three of the four trials indicated that there was significantly less growth hormone, per unit of glandular powder, in the glands from dwarf calves than in those from normal calves ($P<.01$).

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CARCASS CHARACTERISTICS OF PUREBRED AND CROSSBRED BEEF STEERS IN THE GULF COAST REGION [1]

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THE lack of facilities and the large expense involved in obtaining carcass information have severely limited knowledge of the carcass characteristics of the many types of beef cattle produced in this country. The need for this information is obvious if the quality of the beef produced is to be maintained at the high level demanded by the consumer. The characteristics and amount of variation present in our breeds and crosses must be assessed as accurately as possible if intelligent breeding plans are to be formulated for the improvement of cattle.

Most meat investigations have been concerned with the evaluation of different feedstuffs, feed additives, or feeding regimes. A relatively small amount of work has been done to determine differences in carcass characteristics within and among breeds of cattle with a view toward evaluating possible improvement through genetic methods. Studies such as those of Cover *et al.* (1957) and Black *et al.* (1934) have shown clearly that such differences are pronounced. The assessment of the breeding values of sires and dams through the carcass evaluation of their male offspring is naturally a time-consuming process, thus creating demands by breeders for methods of evaluating live animals in terms of carcass characteristics. Bratzler (1958), in a review of progress in meat research, expressed the belief that these demands will eventually be satisfied. However, such methods are not available at present so information is dependent upon carcass determinations. The work reported herein contains carcass information obtained from 275 steers, made up of 4 purebred and 20 crossbred groups.

Experimental

The data reported in this paper are a part of the results of a crossbreeding study initiated by the Louisiana Agricultural State Experiment Station in 1952 for the purpose of evaluating the performance of purebred and crossbred cattle in the Gulf Coast Region. Six herds of cattle were established, each herd being made up of 8 Angus, 8 Brahman, 8 Brangus,

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and 8 Hereford cows. Each of the six herds was bred to a bull of a different breed. The bulls that were used were Angus, Brahman, Brangus, Charolaise, Hereford, and Shorthorn. A new bull was selected to represent these breeds each year and the cow herds were rotated to a bull of a different breed annually. The Brangus cattle were loaned to the Station by the Iberia Livestock Experiment Farm at Jeanerette, Louisiana. These cattle are called Brahman-Angus but are referred to in this paper as Brangus in order to prevent confusion with the crosses of Brahman and Angus cattle that were made. Replacement of females in all breeds was made only when it became necessary due to disease or reproductive failure. The source of the cattle is described in a previous paper (Damon *et al.*, 1959a). Five sires of each of the six breeds of sires and 48 cows of each of the four breeds of females are relatively small samples of the breeds involved. The results of this experiment, therefore, can only be representative of small segments of the breeds of cattle included and many more similar data will be required before an accurate and dependable characterization of the breeds is possible.

The cattle were pasture bred during a breeding season extending from April 1st to July 1st. Each calf was weighed and ear-notched within 24 hours of birth and a record was made of the weight, sex, date of birth and color of calf. The male calves were castrated and all calves showing horns were dehorned on approximately April 1st each year. All calves were weaned at the same time when the average age of the calves was 8 months.

The steers were kept in a small holding lot for 14 days after weaning and started on a small amount of grain plus hay. At the end of the two-week period the steers were moved to a 50-acre pasture of wheat and rye grass where they remained for the duration of a 168-day feeding period. During the feeding period the steers were limited-fed approximately seven and one-half pounds of a 6 parts cracked corn and 1 part cottonseed meal concentrate ration. The steers were afforded no shelter other than a few scattered trees in the pastures. As pointed out in a previous paper (Damon *et al.*, 1959b), weather conditions had a marked effect on the pasture development and the rate of gain of the steers. The steers were weighed every 28 days throughout the course of the feeding period.

At the close of the feeding period, the steers were graded by a committee of animal husbandry workers at the University and then transported to the meats laboratory where they were slaughtered. A warm dressed weight was recorded at the time of slaughter and after a 72-hour chilling period the carcasses were graded and the cold dressed weight recorded. Usually the same workers who graded the animals on foot also graded the carcasses. The grading committee used the USDA grading chart 102 and scored each of the items included on the chart. At the time of grading the steers were ribbed down and a tracing made of the rib eye area. The 9-10-11th rib roast was removed from the left side of each carcass and used for cooking, tenderness and chemical studies. The 9-10-11th rib

roast was removed from the right side of the carcass and used in physical separation studies.

The first phase of this crossbreeding study was conducted for a five-year period during which a total of 597 calves were weaned, 275 of which were steers. The data were analyzed by the method of fitting constants for a two-way classification with no interaction, as described by Kempthorne (1952). Tests of significance were made among the sire groups and the dam groups by the New Multiple Range Test as described by Duncan (1955, 1957) and Kramer (1956, 1957).

The model used in the analysis was:

$$y_{ijk} = \mu + a_i + b_j + e_{ijk}$$

where y_{ijk} = the observation of the k^{th} animal for the j^{th} breed group in the i^{th} year

μ = an effect common to all animals

a_i = an effect common to all animals born in the i^{th} year

b_j = an effect common to all animals born in the j^{th} breed group

e_{ijk} = an effect peculiar to each individual animal

$i = 1,\ldots,5$

$j = 1,\ldots,24$

Results and Discussion

A large number of measurements and determinations were made on the steers produced in this study in order to get as accurate an evaluation of the different types of breeding as possible. In order to study the results of the experiment, the data have been grouped by breed of sire, breed of dam, and also by the breeding of the sire and dam of each group. The number of steers sired by the six breeds of sire did not vary widely, ranging from 42 to 50 and the number of steers raised by each of the four breeds of dams also showed a narrow range of 67 to 71. However, there was a large variation in the number of steers in the 24 different types of breeding, the number per group ranging from 8 to 18.

Slaughter Weights and Grades

Slaughter Weights. The slaughter weights attained by the steers in this study are presented in table 1, together with the number of animals per group and the standard errors of the means. The least squares means obtained from the analysis using the given model are presented first. Subsequent to the calculation of these means it was felt that an investigation of the influences of the age of dam and age of steer on slaughter weight was necessary. A separate least squares analysis was made on a within year-breed group basis to estimate these influences. This analysis showed highly significant effects for both age of dam and age of steer. The individual slaughter weights were then adjusted accordingly and a second least squares analysis made which resulted in the second set of means

TABLE 1. LEAST SQUARES MEANS AND STANDARD ERRORS OF SLAUGHTER WEIGHTS AND SLAUGHTER GRADES WITH TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS [a]

Breed of sire	No. of steers	Slaughter weight (lb.)	Slaughter weight (lb.) (adjusted) [b]	Slaughter grade (adjusted) [c]
Angus	49	706.3±12.7	709.6±10.6	11.0±.19
Brahman	42	734.0±13.3	749.9±11.1	10.6±.20
Brangus	43	717.4±13.3	709.1±11.1	10.0±.20
Charolaise	44	802.0±13.5	779.0±11.3	9.8±.20
Hereford	47	772.9±12.8	752.6±10.7	11.2±.19
Shorthorn	50	749.2±12.7	757.4±10.6	11.2±.19
			(C,S,H,B) (A,BA) [d, e]	(H,S,A,B) (BA,C)
Breed of dam				
Angus	67	748.0±10.8	730.9±9.0	10.8±.16
Brahman	70	730.5±10.8	741.3±9.0	10.4±.16
Brangus	71	764.1±10.4	757.9±8.6	10.1±.15
Hereford	67	745.2±10.5	741.7±8.8	11.1±.15
			(BA,H,B) (H,B,A)	(H,A) (A,B) (B,BA)
Breed group				
A x A	10	698.4±27.3	693.2±22.7	11.2±.40
A x B	18	720.6±20.4	740.9±17.0	10.9±.30
A x BA	10	736.8±27.3	746.8±22.7	10.4±.40
A x H	11	669.4±26.1	657.5±21.7	11.5±.38
B x A	11	797.0±26.0	797.7±21.6	11.1±.38
B x B	10	631.3±27.3	656.3±22.7	10.3±.40
B x BA	10	751.9±27.2	761.4±22.7	9.8±.40
B x H	11	755.7±26.2	784.1±21.8	11.4±.38
BA x A	9	701.7±28.8	678.4±24.0	9.7±.42
BA x B	13	691.2±23.9	694.2±19.9	10.3±.35
BA x BA	10	730.9±27.3	703.4±22.8	9.2±.40
BA x H	11	745.8±26.2	760.6±21.8	10.7±.38
C x A	10	836.9±27.4	795.8±22.9	10.4±.40
C x B	8	755.1±30.5	758.8±25.4	9.4±.45
C x BA	15	795.0±22.5	774.0±18.7	9.4±.33
C x H	11	820.9±26.3	787.2±21.9	9.9±.39
H x A	11	741.3±26.1	702.3±21.7	11.5±.38
H x B	13	802.7±23.9	801.5±19.9	10.9±.35
H x BA	12	797.5±25.0	774.4±20.8	10.9±.37
H x H	11	750.3±26.0	732.1±21.7	11.4±.38
S x A	16	712.7±21.5	717.7±17.9	10.8±.32
S x B	8	782.2±30.6	795.9±25.5	11.0±.45
S x BA	14	772.6±23.0	787.3±19.2	11.1±.34
S x H	12	729.4±25.0	728.9±20.8	11.7±.37

[a] Grading system: 17–15, prime; 14–12, choice; 11–9, good; 8–6, commercial; 5–3, utility.
[b] Slaughter weights adjusted for age of dam and for age of steer.
[c] Adjusted for slaughter weights.
[d] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).
[e] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

presented in table 1. The weights were adjusted first to the final average age of 421 days by the regression of 1.45 lb. Adjustment was then made for the age of the dam by subtracting 21 lb. from the weights of steers born to dams 7 years and older, adding 16 lb. to steers from 4-year-old dams, and adding 48 lb. to steers from 3-year-old dams. While this procedure is not the most accurate it was the most expedient since the adjustments for the effects of the age of dam and age of steer were not thought necessary until after the matrix for the years and crosses had already been inverted.

Tests of significance among the groups of steers sired by different breeds of bulls showed that the adjusted slaughter weights of the steers sired by Charolaise, Shorthorn, Hereford, and Brahman bulls did not differ significantly from one another but that these steers were significantly heavier than the steers sired by the Angus and Brangus bulls. Tests of significance were made also among the steers out of the four different breeds of dams and it was found that there were no significant differences among the weights of the steers having Brangus, Hereford, and Brahman dams, although the steers out of Brangus cows were significantly heavier than the steers out of Angus cows. There were wide differences among the adjusted final weights of the steers in the individual breed groups, with a range of 656 to 802 lb. The differential response of cows of Brahman or Brangus breeding and cows of British breeding was very noticeable when the steer groups sired by the Angus, Hereford and Shorthorn bulls were examined, the former groups of steers being considerably heavier in every case. Since previous papers (Damon *et al.*, 1959a, 1959b) have shown that the calves out of Brahman and Brangus cows were heavier at weaning and that steers out of Angus and Hereford cows gained more rapidly on feed, it appears that the heavier steers retained a large amount of the initial weight advantage throughout the feeding period. This behavior did not appear to hold with the steers sired by the Charolaise bulls as the steers out of Brahman and Brangus dams gained at a good deal slower rate on feed than did the steers out of the Angus and Hereford dams.

Slaughter Grades. Although the least squares means for slaughter grades have been presented previously (Damon *et al.*, 1959b), it was felt that an examination of the influence of slaughter weight on these grades might be of importance. A least squares analysis on a within year-breed group basis showed a highly significant regression of slaughter grade on slaughter weight of 0.0091. The individual grades were adjusted to the average final weight of 746 lb. and a second least squares analysis was made. The slaughter grades resulting from this analysis are presented in table 1. Tests of significance among the sire groups showed that there were no significant differences among the steers sired by the Hereford, Shorthorn, Angus and Brahman bulls, while all of these steers had significantly higher slaughter grades than did the steers sired by the Brangus and Charolaise bulls. Among the steers out of the four different breeds of dams it was found

that the steers out of Hereford dams had significantly higher slaughter grades than did the steers out of the Brahman and Brangus cows. The steers out of Angus dams did not differ significantly from those out of Brahman dams although their grades were significantly higher than the steers out of Brangus dams. Again wide differences were noticeable among the individual breed groups with a range in grade from 9.2 to 11.8. In general it was found that steers with large amounts of Brahman breeding and steers with Charolaise breeding received the lower grades while those steers of the British breeds or breed crosses received the higher grades.

Carcass Grade, Cold Dressing Percent, Area of Rib Eye, and Shearing Strength

Carcass Grades. The animals were removed from the coolers after a 72-hour period and numerous measurements and grades were obtained from each carcass. One of the more important criteria of evaluation was the carcass grade. An analyis of the data revealed that there was a highly significant regression of carcass grade on slaughter weight of 0.0106. This figure is in close agreement with that found by Magee *et al.* (1958) of .0071. The carcass grades were then adjusted to an average slaughter weight of 746 lb. and the adjusted means are presented in table 2. When the steers were grouped by breed of sire, large differences in carcass grades were found. The steers sired by Angus and Shorthorn bulls received grades which were significantly higher than those of the steers sired by the other four breeds of bulls. The steers sired by the Hereford bulls ranked next and significantly higher than the remaining groups. The steers sired by the Brangus and Brahman bulls did not differ significantly in grade, but both were significantly higher than the steers sired by the Charolaise bulls. These results are in agreement with those of Peacock and Kirk (1958) who reported that in crossing Brahman and Shorthorn cattle, as the amount of Shorthorn breeding in the crosses increased, there was a corresponding increase in carcass grade. Ittner (1954) found that Brahman x Hereford carcasses were superior to Brahmans, but were not as attractive to the graders as Hereford and Shorthorn x Hereford crossbred carcasses. Hubert (1955) also reported that in a comparison of Brahman x Hereford with Hereford steers there was a much higher percentage of choice carcasses among the Herefords than among the Brahman x Herefords. However, Black *et al.* (1934) found that in a comparison of Hereford and Shorthorn steers with Brahman crossbreds although the Herefords and Shorthorns graded somewhat higher on the average, as feeders and slaughter cattle, the differences in carcass grades were very much less and favored the Brahman crossbreds about as often as they did the non-Brahmans.

When the steers were grouped by breed of dam, it was found that steers out of females of British breeding attained higher carcass grades than did steers raised by Brahman and Brangus dams. Steers out of Angus cows

TABLE 2. LEAST SQUARES MEANS AND STANDARD ERRORS OF CARCASS GRADES, COLD DRESSING PERCENTS, AREAS OF RIB EYE, AND SHEARING STRENGTHS WITH TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS [a]

Breed of sire	No. of steers	Carcass grade (adjusted) [b]	Cold dressing percent (adjusted) [b]	Area of rib eye (adjusted) [b] (sq. in.)	Shearing strength (lb.) [c]
Angus	49	11.4±.18	56.6±.30	8.8±.18	14.1±.66
Brahman	42	9.9±.19	57.7±.31	8.6±.18	17.2±.70
Brangus	43	10.1±.19	56.7±.31	9.0±.18	16.3±.69
Charolaise	44	9.0±.20	57.1±.31	9.2±.19	14.0±.70
Hereford	47	10.8±.19	56.0±.30	8.6±.18	14.3±.67
Shorthorn	50	11.3±.18	56.8±.29	8.2±.18	14.3±.66
		(C) [d, e]	(S,BA,A,H)	(H,B,S)	
		(A,S) (H)	(B,C,S)	(C,BA,A)	(B,BA)
		(BA,B)	(C,S,BA,A)	(BA,A,H,B)	(H,S,A,C)
Breed of dam					
Angus	67	11.3±.16	57.0±.25	8.8±.15	15.0±.56
Brahman	70	9.7±.16	57.4±.25	8.7±.15	16.8±.56
Brangus	71	9.9±.15	56.4±.24	8.7±.14	14.3±.54
Hereford	67	10.8±.15	56.5±.24	8.7±.15	14.1±.55
		(A) (H) (BA,B)	(B,A) (A,H,BA)	(A,BA,H,B)	(B) (A,BA,H)
Breed groups					
A x A	10	12.1±.39	56.9±.63	9.0±.38	14.4±1.42
A x B	18	10.6±.29	56.8±.47	8.6±.28	15.9±1.06
A x BA	10	11.2±.39	56.1±.63	8.9±.38	14.2±1.42
A x H	11	11.8±.38	56.5±.61	8.7±.36	12.1±1.36
B x A	11	11.1±.37	57.8±.60	8.6±.36	15.3±1.35
B x B	10	9.2±.39	58.0±.63	8.4±.38	20.4±1.42
B x BA	10	9.2±.39	57.1±.63	8.6±.38	17.3±1.42
B x H	11	10.4±.38	57.8±.61	8.8±.36	15.7±1.36
BA x A	9	11.3±.42	57.7±.67	9.0±.40	18.5±1.50
BA x B	13	9.8±.35	57.9±.56	9.2±.33	17.0±1.25
BA x BA	10	9.1±.39	55.4±.64	9.0±.38	14.7±1.42
BA x H	11	10.2±.38	56.0±.61	8.7±.36	15.2±1.36
C x A	10	9.8±.40	56.8±.64	9.3±.38	13.7±1.43
C x B	8	8.1±.44	58.0±.71	9.5±.42	15.5±1.59
C x BA	15	8.4±.32	56.6±.52	8.9±.31	13.1±1.17
C x H	11	9.6±.38	56.8±.61	9.1±.36	13.5±1.37
H x A	11	11.6±.38	55.8±.61	8.6±.36	14.7±1.36
H x B	13	10.5±.35	56.6±.56	8.2±.33	15.5±1.25
H x BA	12	9.7±.36	55.6±.58	8.8±.35	13.6±1.30
H x H	11	11.3±.38	55.8±.61	8.7±.36	14.4±1.36
S x A	16	12.1±.31	56.8±.50	8.3±.30	13.3±1.12
S x B	8	9.8±.44	57.1±.71	8.1±.42	16.3±1.59
S x BA	14	11.7±.33	57.4±.54	8.2±.32	14.1±1.20
S x H	12	11.5±.36	56.1±.58	8.2±.35	13.4±1.30

[a] Grading system: 17–15, prime; 14–12, choice; 11 9, good; 8–6, commercial; 5–3, utility.
[b] Adjusted for slaughter weight.
[c] Warner-Bratzler shear reading. The shear tests were made on one inch cores.
[d] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).
[e] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

received significantly higher grades than did steers from the other three breeds of cows and steers from Hereford cows received grades that were significantly higher than those of steers from Brangus and Brahman cows, which did not differ significantly from each other. The finding corresponds with that of Baker and Black (1950) who found that purebred Angus steers reached the highest carcass grades, with a decrease in carcass grade as the amount of Brahman breeding increased in Brahman x Angus crosses.

Although tests of significance were not made among the 24 different breed groups, very large differences in grades were noticeable, with a range of 8.1 to 12.1. An examination of these breed groups revealed that, in general, until the amount of Brahman breeding exceeded 50%, adverse effects were not apparent in the carcass grades of the steers. The Charolaise crosses reflected a marked lack of finish when Brahman and Brangus cows were the dams with a noticeable increase when Angus and Hereford cows were utilized in the cross. Comparisons of the average of Angus and Hereford with their reciprocal crosses showed their carcass grades to be not significantly different from one another. However, Gerlaugh (1951) in similar comparisons, including heifers, found that the crossbreds from Angus cows produced the highest proportion of choice carcasses. The purebred Angus steers and heifers were second, followed by the crossbreds from the Hereford cows, and the purebred Herefords, in fourth position, respectively. These differences were statistically significant.

Cold Dressing Percents. The cold dressing percents were calculated on the carcasses after a 72-hour period in the coolers. The results are presented in table 2. When grouped by breed of sire it was found that the steers sired by Brahman bulls had significantly higher dressing percents than did the steers sired by Brangus, Angus, and Hereford bulls although they did not differ significantly from the steers sired by the Charolaise and Shorthorn bulls. Steers sired by the bulls of the three British breeds did not differ significantly from one another. When examined by breed of dam it was found that steers out of Brahman females had cold dressing percents that were significantly greater than the steers out of Hereford and Brangus cows. The cold dressing percents of steers out of Angus, Hereford, and Brangus cows did not differ significantly from one another. Examination of the 24 breed groups showed that, in general, the Brahman crossbreds produced higher yields than did steers of the British breeds, or crosses among the British breeds. Straightbred or crossbred British steers had an average of 56.3 cold dressing percent, steers of British x Brangus breeding had an average 56.6 cold dressing percent, steers of British x Brahman breeding had an average of 57.2 cold dressing percent, and steers of Brangus, Brahman, or Brangus x Brahman breeding had an average of 57.1 cold dressing percent. The last figure was lowered considerably by the particularly low value of the straightbred Brangus steers. Although the differences were not as great as those reported by Black *et al.* (1934), who found that dressing percentages of steers of Brahman breeding were consistently greater than those of Herefords and Shorthorns, the trends were

similar. In a comparison of dressing percentages of Brahman x Hereford with Hereford steers, Hubert (1955) found a difference of 1.8% in favor of the crossbreds which is in close agreement with the difference of 2.0% found in this study in a comparison of the same breed groups. Although Baker and Black (1950), in a comparison of purebred Angus with Angus x Brahman crossbred steers, found that crossbreds exceeded the purebreds in carcass yields, this study did not obtain the same results. Comparisons among Angus, Hereford and reciprocal cross steers in this study showed their yields to be not greatly different. Gerlaugh (1951), however, in comparisons among these same types of cattle, found that crossbred steers and heifers from Angus cows dressed slightly higher than any other group. The purebred Hereford steers and heifers dressed significantly lower than any other group. The crossbreds from the Hereford cows dressed slightly, not significantly, more than the purebred Angus steers and heifers. In another study of crossing the British breeds, Knapp *et al.* (1949) found that Shorthorn x Hereford crossbred heifers were significantly superior to Hereford steers in dressing percentage. While the difference was in the same direction in this study, it was not great enough for statistical significance.

Rib Eye Area. The area of the longissimus dorsi muscle, or rib eye, is commonly relied on to yield an estimate of the amount of lean meat in the carcass, and thus is a valuable criterion of evaluation of the carcass. Since there was a large amount of variation among the final weights, a least squares analysis of the regression of rib eye area on slaughter weight on a within year-breed group basis was made. The analysis revealed that there was no significant curvilinear relationship between rib eye area and slaughter weight. However, there was a highly significant linear relationship which yielded a regression coefficient of 0.0089 sq. in. This is a little higher than the figure of 0.0051 arrived at by Magee *et al.* (1958). The individual rib eye measurements were adjusted to the average slaughter weight of 746 lb. and a least squares analysis made of these data. The resulting means and tests of significance are shown in table 2. Considerable interest has been manifested in the lean meat content of the Charolaise cattle in this country, and when the steers were grouped by breed of sire it was found that these steers ranked first and had an average rib eye area that was significantly larger than the steers sired by Hereford, Brahman, and Shorthorn bulls although not significantly different from the steers sired by the Brangus and Angus bulls. The steers sired by the Shorthorn bulls, which ranked high in carcass grade, ranked the lowest in rib eye area and were significantly smaller in rib eye area than the steers sired by Charolaise, Brangus, and Angus bulls. When grouped by breed of dam, the differences in rib eye area were not great and showed no statistical significance. An examination of the rib eye areas of the 24 breed groups demonstrated fairly wide differences in size, ranging from 8.1 to 9.5 sq. in. The larger areas attained by the Charolaise crosses are quite

evident as three of the four crosses exceeded nine square inches, in contrast to the Shorthorn crosses, all of which were noticeably small. The Brangus cattle, whether used as sires or dams, ranked among the top groups with respect to this trait, although the Brahman cattle ranked quite low. In a comparison of Hereford and Hereford x Brahman crossbreds, Cartwright *et al.* (1958) found that the area of eye muscle was higher for crossbreds because they were heavier, but smaller per 100-lb. carcass weight because eye muscle development was not directly proportional to weight increase. When the eye muscle areas were adjusted according to the formula reported by Butler (1957), the areas were very similar.

Shearing Strength. The shearing strengths, as measured by the Warner-Bratzler shear test, showed wide variations from year to year and also within years, as indicated by the large standard errors attached to the least squares means shown in table 2. Tests of significance among the sire groups showed clearly that the steers fell into two groups, with those steers sired by Brahman and Brangus sires having significantly higher shearing values than the steers sired by the other four breeds of sire, which were quite similar in this respect. Those steers raised by Brahman dams also yielded significantly higher shear test readings than the steers raised by the Angus, Brangus, and Hereford dams which yielded estimates that did not differ greatly. Great variations were exhibited among the 24 breed groups, values ranging from 12.1 lb. to 20.4 lb. These results demonstrate that in this study the steers of Brahman breeding yielded meat that was considerably more resistant to the shearing test while the other types of breeding did not differ greatly in this trait. These findings are similar to those of Black *et al.* (1934) who reported that the meat of Brahman x Shorthorn steers was less tender than comparable Hereford and Shorthorn steers. However, they found wide variations among individual animals as has been observed also by Cover *et al.* (1957).

Carcass Conformation

Compactness. Visual appraisal of steers as outlined in USDA chart 102 considers the carcass under three categories, conformation, finish, and quality. These categories are broken down into several parts, each of which is considered in this report. Table 3 presents the results of the appraisals of carcass conformation. The steers sired by the six different breeds of sire fell into two very distinct groups when appraised for compactness as can be observed from this table. The steers sired by bulls of British breeding received compactness scores that were significantly higher than those of the steers sired by Charolaise, Brangus, and Brahman sires, with very similar scores received within each of the two groups. Again, when grouped by breed of dam, the steers fell into two distinct groups with those steers raised by dams of the Angus and Hereford breeds receiving scores that were significantly higher than those steers raised by the Brahman and Brangus dams. The lower compactness scores attached to steers of Brahman breed-

TABLE 3. LEAST SQUARES MEANS AND STANDARD ERRORS OF CARCASS CONFORMATION SCORES AND TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS [a]

Breed of sire	No. of steers	Compactness	Thickness of carcass	Rib eye (lean)	Loin	Round
Angus	49	11.5±.27	11.5±.23	11.0±.27	11.1±.24	10.6±.30
Brahman	42	10.2±.28	10.5±.25	10.6±.29	10.3±.26	10.2±.32
Brangus	43	10.4±.28	10.4±.24	11.2±.29	10.5±.25	9.5±.31
Charolaise	44	10.5±.28	10.6±.25	12.3±.29	10.9±.26	10.2±.32
Hereford	47	11.7±.27	11.9±.24	12.1±.28	11.6±.25	11.3±.30
Shorthorn	50	11.7±.26 (H,S,A) (C,BA,B) [b, c]	12.2±.23 (S,H)(H,A) (C,B,BA)	11.6±.27 (C,H,S) (S,BA,A) (BA,A,B)	11.7±.24 (S,H,A)(H,A,C) (A,C,BA) (C,BA,B)	11.5±.30 (S,H)(H,A) (A,C,B) (C,B,BA)
Breed of dam						
Angus	67	12.0±.22	11.8±.20	11.9±.23	11.6±.21	11.4±.25
Brahman	70	10.3±.23	10.5±.20	10.9±.23	10.6±.21	9.7±.25
Brangus	71	10.3±.22	10.9±.19	11.3±.22	10.6±.20	10.0±.24
Hereford	67	11.4±.22 (A,H)(B,BA)	11.4±.19 (A,H)(H,BA) (BA,B)	11.8±.23 (A,H,BA) (BA,B)	11.2±.20 (A,H) (H,BA,B)	11.0±.25 (A,H)(BA,B)
Breed group						
A x A	10	12.4±.57	12.0±.50	11.2±.59	11.5±.52	10.9±.64
A x B	18	10.9±.43	11.1±.37	10.9±.44	10.9±.39	10.3±.48
A x BA	10	11.5±.57	11.5±.50	10.5±.59	10.9±.52	10.4±.64
A x H	11	11.4±.55	11.3±.48	11.3±.56	11.1±.50	10.9±.62
B x A	11	12.4±.54	12.4±.48	12.1±.56	11.8±.50	12.1±.61
B x B	10	8.4±.57	8.3±.50	8.4±.59	8.5±.52	8.2±.64
B x BA	10	9.1±.57	9.9±.50	10.4±.59	10.0±.52	9.2±.64
B x H	11	10.9±.55	11.4±.48	11.4±.56	11.0±.50	11.2±.62
BA x A	9	11.0±.60	11.1±.53	10.9±.62	11.3±.55	10.6±.68
BA x B	13	9.9±.50	9.9±.44	10.8±.52	10.3±.46	8.6±.56
BA x BA	10	9.9±.57	9.7±.50	11.6±.59	9.7±.52	8.6±.65
BA x H	11	10.7±.55	11.0±.48	11.5±.56	10.7±.50	10.1±.62
C x A	10	11.6±.57	11.4±.50	13.6±.59	11.3±.53	11.6±.65
C x B	8	9.4±.64	9.9±.56	11.8±.66	11.1±.58	9.3±.72
C x BA	15	9.6±.47	10.2±.41	11.6±.48	10.1±.43	9.7±.53
C x H	11	11.2±.55	10.7±.48	12.4±.57	11.0±.50	10.2±.62
H x A	11	12.4±.55	11.9±.48	12.1±.56	11.7±.50	11.5±.62
H x B	13	11.6±.50	12.2±.44	12.0±.52	11.7±.46	11.3±.56
H x BA	12	10.5±.52	11.3±.46	11.7±.54	11.1±.48	10.1±.59
H x H	11	12.5±.54	12.0±.48	12.6±.56	11.8±.50	12.3±.61
S x A	16	12.2±.45	12.2±.40	11.4±.46	12.1±.41	11.6±.51
S x B	8	11.6±.64	11.8±.56	11.4±.66	11.3±.59	10.8±.72
S x BA	14	11.0±.48	12.8±.42	12.1±.50	12.2±.44	12.2±.54
S x H	12	12.0±.52	11.9±.46	11.3±.54	11.4±.48	11.5±.59

[a] Carcasses were scored on U.S.D.A. Beef Carcass Grading Chart No. 102, using the following numbers: 17–15, prime; 14–12, choice; 11–9, good; 8–6, commercial; 5–3, utility.

[b] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).

[c] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

ing is brought out clearly in a study of the 24 breed groups. However, it can also be seen that unless the Brahman breeding exceeds 50% it does not appear to influence the compactness scores adversely, as most of the crosses involving British and Brahman breeding received relatively good scores. The steers of British breeding received the highest grades as was evidenced by the fact that all breed groups receiving a score of 12 or above were of this type with the exception of the Brahman x Angus group.

Thickness of Carcass. Scores for thickness of carcass fell into the same pattern as those for conformation of carcass, with those steers sired by bulls of British breeding ranking higher than those of Charolaise and Brahman breeding, as shown in table 3. The steers of Shorthorn breeding received the highest scores for this trait, scores which were significantly higher than all others except the steers sired by the Hereford bulls. The steers raised by females of the Angus and Hereford breeds also received higher scores than those raised by females of the Brangus and Brahman breeding. Scores of the 24 breed groups followed closely the scores attained for compactness, as the British cattle showed thicker carcasses, while the Brahman and Charolaise cattle ranked low in this characteristic.

Rib Eye. Visual appraisal of the rib eye area is an attempt to evaluate not only the size but also the shape and general appearance of the rib eye and it was found that these scores did not agree in some respects with the areas of rib eye as measured by planimeter readings. The scores received by the different sire groups are shown in table 3, and it was found that the Charolaise steers ranked first as they did in the measurements of rib eye area, although the scores did not differ significantly from those of the steers sired by the Hereford and Shorthorn bulls. In spite of the fact that the steers sired by Shorthorn bulls yielded the smallest area of rib eye, in the visual appraisal they ranked third. When grouped by breed of dam, it was found that the steers raised by Angus and Hereford cows ranked higher in this characteristic than did the steers raised by Brangus and Brahman cows. When the breed groups were examined it was found that, in general, the steers of the British breeds were scored higher for rib eye than the steers of Brahman breeding.

Loin. The scores of the appraisals of the length, width, and general appearance of the loin which are presented in table 3, showed that the steers of British breeding received higher scores than did the steers of Brahman breeding, while the crossbred Charolaise steers were intermediate in rank. When examined by breed of dam it was again apparent that the steers out of British females were superior in this trait to steers out of Brangus or Brahman females. The scores of the 24 breed groups reflect the differences that were observed by grouping the steers by breed of sire or breed of dam. It was noticeable again that although the Brangus steers did not contain as much Brahman breeding as did many of the crosses, their carcasses were scored more like the purebred Brahmans than like the British breeds.

Round. The scores for evaluation of the round presented in table 3, again emphasized the fact that the British cattle received higher scores for carcass characteristics than did the Brahman, Brangus, or Charolaise cattle. When grouped by breed of sire, it was found that the Shorthorn, Hereford, and Angus steers ranked higher in conformation of round than the Charolaise, Brahman, and Brangus steers. It was also found that steers raised by Angus and Hereford cows received scores for the round which

were significantly higher than those received by the steers raised by the Brangus or Brahman cows. A study of the scores received by the 24 breed groups brings out clearly the generally poorer scores received by Brahman and Brahman crossbred cattle for carcass conformation characteristics in this experiment. It is interesting to note that for all five characteristics considered in the evaluation of conformation, the steers sired by Hereford bulls consistently ranked ahead of the steers sired by Angus bulls, while the steers raised by Angus cows were consistently ranked higher than those raised by Hereford cows. This may be the result of sampling, but further data will be required to determine whether this situation is generally prevalent.

Carcass Finish Characteristics

Thickness of Fat (external). The increasing emphasis on carcass evaluations, consumer preference studies, and in general a more intense effort to determine the criteria which define a good beef carcass, make the measurement of the finish of carcasses of considerable importance. The first criterion of finish as listed on USDA chart 102 is the thickness of external fat. The data resulting from this study are presented in table 4, where it can be seen that there were very wide differences in the scores for this trait. Steers sired by Shorthorn, Angus, and Hereford bulls were not significantly different but all differed significantly from the steers sired by Brahman, Brangus, and Charolaise bulls. The steers sired by the Charolaise bulls had significantly lower scores for thickness of external fat than all other steers. When grouped by breed of dam considerable differences in scores were again noticeable. The steers raised by Angus cows had significantly higher scores for this trait than steers raised by the three other breeds of cows, while the steers raised by Hereford cows had significantly higher scores than those raised by Brangus and Brahman cows. The breed groups naturally show these large differences in more detail, with a range in averages score from 5.4 to 11.8. A study of these groups shows clearly the low scores received by all Charolaise crosses and the low scores that were, in general associated with Brahman and Brangus crosses.

Distribution of Fat (external). The scores received by the steers for the distribution of external fat followed very much the same pattern as the scores for thickness of external fat. It can be seen from table 4 that steers sired by bulls of the British breeds again ranked higher than the steers sired by Brahman, Brangus, and Charolaise bulls, although the differences were not as pronounced for this trait. The steers raised by Angus cows had scores that were significantly higher than the scores of the steers raised by the other three breeds of cows for this trait also, and the steers raised by Hereford cows received grades that were significantly higher than the scores of the steers raised by Brangus and Brahman cows. The scores received by the breed groups brought out again the low scores received by the steers exceeding 50% Brahman breeding, and also that the straight

TABLE 4. LEAST SQUARES MEANS AND STANDARD ERRORS OF CARCASS FINISH SCORES AND TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS [a]

Breed of sire	No. of steers	Thickness of fat (external)	Distribution of fat (external)	Kidney knob	Marbling (in rib eye)
Angus	49	10.3±.34	11.2±.25	10.3±.36	7.2±.39
Brahman	42	8.5±.35	10.0±.27	8.9±.37	4.3±.41
Brangus	43	8.3±.35	9.9±.27	9.9±.37	5.5±.40
Charolaise	44	7.3±.36	9.6±.27	8.9±.38	4.2±.41
Hereford	47	10.2±.34	11.6±.26	10.2±.36	6.2±.39
Shorthorn	50	11.1±.34	12.0±.25	11.4±.36	7.2±.39
		(S,A,H) (B,BA) [b, c] (C)	(S,H) (H,A) (B,BA,C)	(S) (A,H,BA) (BA,C,B)	(S,A,H) (H,BA) (B,C)
Breed of dam					
Angus	67	10.7±.29	11.7±.21	11.0±.30	7.2±.33
Brahman	70	8.1±.29	9.9±.22	9.1±.30	4.3±.33
Brangus	71	8.4±.28	10.2±.21	9.6±.29	5.7±.32
Hereford	67	9.9±.28	11.1±.21	10.0±.29	6.0±.32
		(A) (H) (BA,B)	(A) (H) (BA,B)	(A) (H,BA) (BA,B)	(A) (H,BA) (B)
Breed group					
A x A	10	11.4±.72	11.7±.54	11.1±.76	9.6±.83
A x B	18	9.4±.54	10.7±.41	9.9±.57	5.0±.62
A x BA	10	10.4±.72	11.3±.54	10.8±.76	7.6±.83
A x H	11	10.1±.69	11.1±.52	9.4±.73	6.5±.79
B x A	11	11.2±.69	12.1±.52	11.2±.73	6.1±.79
B x B	10	5.6±.72	8.0±.54	5.5±.76	2.5±.83
B x BA	10	7.5±.72	9.1±.54	9.1±.76	4.2±.83
B x H	11	9.7±.69	10.9±.52	9.8±.73	4.6±.79
BA x A	9	10.2±.77	11.1±.58	8.8±.81	6.9±.88
BA x B	13	7.8±.64	9.2±.48	10.7±.67	4.9±.73
BA x BA	10	6.7±.73	8.9±.55	7.6±.77	4.6±.83
BA x H	11	8.6±.69	10.4±.52	9.8±.73	5.6±.79
C x A	10	9.1±.73	11.2±.55	10.5±.77	5.3±.83
C x B	8	5.4±.81	8.7±.61	7.5±.85	2.6±.93
C x BA	15	5.9±.60	8.5±.45	8.0±.63	4.1±.68
C x H	11	8.7±.70	10.3±.53	9.5±.74	5.0±.80
H x A	11	10.8±.69	12.1±.52	10.2±.73	7.4±.79
H x B	13	10.7±.64	11.7±.48	11.0±.67	5.3±.73
H x BA	12	8.4±.66	10.7±.50	8.9±.70	5.3±.76
H x H	11	11.0±.69	12.0±.52	10.7±.73	6.7±.79
S x A	16	11.6±.57	12.2±.43	11.9±.60	7.9±.65
S x B	8	9.8±.81	11.0±.61	10.0±.86	5.4±.93
S x BA	14	11.8±.61	12.7±.46	12.7±.65	8.1±.70
S x H	12	11.1±.66	11.9±.50	11.0±.70	7.4±.76

[a] Carcasses were scored on U.S.D.A. Beef Carcass Grading Chart No. 102, using the following numbers: 17–15, prime; 14–12, choice; 11–9, good; 8–6, commercial; 5–3, utility.

[b] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).

[c] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

Brangus steers received scores more in keeping with Brahman breeding rather than British breeding, even though they averaged only three-eighth Brahman breeding. The Charolaise crosses also graded low in the scores for this characteristic, as they did for thickness external fat.

Kidney Knob. The scores for kidney knob presented in table 4 showed that those steers sired by Shorthorn bulls had a significantly larger kidney knob than the steers sired by the five other breeds of sires, with the steers sired by bulls of the British breeds receiving higher scores for this characteristic than the steers sired by the Brangus, Charolaise, and Brahman sires. When examined by the breed of the dam, the same ranking was found as for the previous two measures of finish, with the steers raised by dams of the British breeds ranking above the steers raised by Brangus and Brahman dams. The scores received by the breed groups again showed that steers with Brahman breeding had smaller kidney knobs than the steers of British breeding. The Charolaise crosses also demonstrated lower scores for this trait.

Marbling. Although considerable work remains to be done to establish the relationship of marbling in the rib eye with the eating quality of beef, it is in general considered to be of importance. Since the steers in this study were finished on pasture with a limited grain supplement, and slaughtered at an early age they showed very little marbling. However, an examination of the marbling scores presented in table 4 showed that there were some wide variations in this respect, not only among breed groups but within breed groups. The standard errors shown for this trait are noticeably larger than those of the three other measures of finish. When examined by breed of sire it was observed that the steers sired by bulls of the British breeds ranked higher than the steers sired by bulls of the Brangus, Brahman, and Charolaise breeds. Steers sired by Brahman and Charolaise bulls were scored significantly lower than the steers sired by the four other breeds of bulls. Steers raised by Angus cows received scores that were significantly higher than the scores received by steers raised by the three other breeds of cows, while the steers raised by Brahman cows received scores that were significantly lower than all others. Extremely wide variations were observed among the breed groups, with a range of 2.5 to 9.6. Although all scores were low, they do indicate that in this study the steers of British breeding demonstrated considerably more marbling than did the steers of Brangus, Brahman, and Charolaise breeding.

Carcass Quality Characteristics

Grain of Lean. Visual appraisals of grain of lean, firmness of lean, color of lean, and color of fat compose the evaluation of carcass quality characteristics on the USDA chart 102. These characteristics are presented in table 5 together with standard errors and tests of significance among sire and dam groups. It can be seen that when scored for grain of lean the

TABLE 5. LEAST SQUARES MEANS AND STANDARD ERRORS OF CARCASS QUALITY SCORES AND TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS [a]

Breed of sire	No. of steers	Grain of lean	Firmness of lean	Color of lean	Color of fat
Angus	49	12.5±.24	12.2±.20	13.4±.22	12.4±.19
Brahman	42	10.9±.25	11.5±.21	13.0±.23	11.7±.20
Brangus	43	11.3±.25	11.7±.21	12.6±.23	12.1±.20
Charolaise	44	11.4±.26	11.7±.21	13.3±.23	12.1±.21
Hereford	47	12.4±.24	12.2±.20	13.2±.22	12.2±.19
Shorthorn	50	12.3±.24	12.9±.20	13.5±.22	12.5±.19
		(A,H,S) (C,BA,B) [b, c]	(S) (H,A,C,BA) (C,BA,B)	(S,A,C,H,B) (H,B,BA)	(S,A,H,BA,C) (H,BA,C,B)
Breed of dam					
Angus	67	12.7±.20	12.4±.17	13.5±.18	12.4±.16
Brahman	70	11.0±.20	11.9±.17	12.5±.18	11.8±.16
Brangus	71	11.4±.20	11.8±.16	13.1±.18	12.1±.16
Hereford	67	12.2±.20	12.1±.17	13.3±.18	12.4±.16
		(A,H) (BA,B)	(A,H) (H,B,BA)	(A,H,BA) (B)	(H,A,BA) (BA,B)
Breed group					
A x A	10	12.6±.52	12.1±.43	13.2±.47	12.1±.41
A x B	18	11.9±.39	12.0±.32	13.4±.35	12.0±.31
A x BA	10	12.6±.52	12.4±.43	13.6±.47	12.6±.41
A x H	11	13.0±.49	12.3±.41	13.4±.45	12.9±.40
B x A	11	12.5±.49	12.7±.41	13.8±.44	12.1±.39
B x B	10	9.6±.52	10.9±.43	12.4±.47	11.5±.41
B x BA	10	9.6±.52	10.7±.43	13.1±.46	11.1±.41
B x H	11	11.9±.50	11.8±.41	12.9±.45	12.1±.40
BA x A	9	12.4±.55	12.0±.45	13.4±.49	12.7±.44
BA x B	13	10.8±.45	11.5±.38	11.4±.41	12.0±.36
BA x BA	10	11.1±.52	11.7±.43	12.8±.47	11.9±.41
BA x H	11	11.0±.50	11.6±.41	12.7±.45	12.0±.40
C x A	10	12.5±.52	12.3±.43	13.0±.47	12.3±.42
C x B	8	10.5±.58	11.7±.48	12.1±.52	11.8±.46
C x BA	15	10.3±.43	10.4±.35	12.3±.38	11.9±.34
C x H	11	12.1±.50	12.5±.41	13.9±.45	12.4±.40
H x A	11	12.7±.49	12.3±.41	13.4±.44	12.4±.40
H x B	13	12.3±.45	12.7±.38	13.3±.41	12.2±.36
H x BA	12	11.5±.47	11.9±.39	12.6±.43	11.8±.38
H x H	11	12.9±.49	11.9±.41	13.4±.44	12.5±.40
S x A	16	13.3±.41	13.1±.34	14.1±.37	12.9±.33
S x B	8	10.7±.58	12.2±.48	12.6±.52	11.1±.46
S x BA	14	13.0±.44	13.4±.36	13.9±.39	13.2±.35
S x H	12	12.2±.47	12.8±.39	13.3±.43	12.7±.38

[a] Carcasses were scored on U.S.D.A. Beef Carcass Grading Chart No. 102, using the following numbers: 17–15, prime; 14–12, choice; 11–9, good; 8–6, commercial; 5–3, utility.

[b] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).

[c] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

steers sired by Angus, Hereford, and Shorthorn bulls received scores that were quite similar, all of these sire groups being scored significantly higher than Charolaise, Brangus, and Brahman sire groups. The steers raised by Angus and Hereford cows were scored in a like fashion and were significantly higher than the steers raised by Brangus and Brahman dams. The scores placed on the breed groups indicated that the British type cattle exhibited a finer grain of lean than did the steers showing larger proportions of Brahman breeding. As with most of the other carcass traits, the difference in response of cows of British breeding and cows of Brahman breeding was very noticeable when comparisons of the four Charolaise crosses were made. Black *et al.* (1934) also found that in texture of cooked meats, roasts from Brahman crossbreds were judged to be slightly, but rather consistently, coarser than those of Herefords and Shorthorns.

Firmness of Lean. The results of the scores for the second criterion of carcass quality, firmness of lean, are presented in table 5. It can be seen that the steers sired by Shorthorn bulls received scores that were significantly higher than the scores of any other sire group. Again, steers of British breeding received higher scores than did the steers of Charolaise and Brahman breeding. When grouped by breed of dam it was observed that the steers raised by Angus and Hereford females received higher scores than the steers raised by Brangus and Brahman cows. Examination of the scores of the 24 breed groups showed that crosses with large amounts of Brahman breeding resulted in lower scores, although most of the Brahman crosses did receive good scores.

Color of Lean. The scores for color of lean showed that the differences were much less for this trait than any of the previous characteristics. The scores received by the sire groups, presented in table 5, were quite similar for all sire groups with the exception of the Brangus steers which received scores that were significantly lower than those of the steers sired by the Shorthorn, Angus, and Charolaise bulls. The scores received by the dam groups again showed less variation than was found in the previous characteristics, as the steers raised by the Angus, Hereford, and Brangus cows were quite similar, all receiving scores that were significantly higher than those of the steers out of Brahman dams. The scores received by the breed groups again showed the tendency for the Brahman and Charolaise cattle to rank low in comparison to the cattle of British breeding for the color of lean. Black *et al.* (1934) also found that comparisons of color of meat were variable and inconclusive. They found that an average of numerical color readings slightly favored the Herefords and Shorthorns in one year, but the next year they favored the Brahman crossbreds to a somewhat greater degree.

Color of Fat. The scores for color of fat showed less variation than did most of the carcass traits previously discussed as there were no significant differences among the first five ranked sire groups, as shown in table 5. The steers sired by the Brahman bulls, however, were significantly lower

in score than those sired by the Shorthorn and Angus bulls. The steers of the different dam groups showed the same pattern, as there were no significant differences among the scores of steers raised by the Hereford, Angus, and Brangus dams, while the steers raised by Brahman dams received scores that were significantly lower than the scores of the steers raised by the Hereford and Angus cows. The scores of the 24 groups showed again that although many Brangus, Charolaise, and Brahman crosses did receive relatively good scores for the color of fat, cattle of British breeding showed a color of fat which the graders found preferable.

Physical Separation

Percent Fat. The percent fat, bone and lean in a carcass is, of course, of primary importance. It would be an extremely expensive and time consuming endeavor to make a complete physical separation of each carcass or even one side of a carcass. Hankins and Howe (1946) have shown that the correlations between the fat, bone, and lean in the 9th, 10th, and 11th rib roast and the fat, bone, and lean in the entire carcass are quite high so it has been customary in many carcass studies to estimate the relative proportions of fat, bone, and lean in the carcass by the yield of 9th, 10th, and 11th rib roast. The results of the physical separations of the 9th, 10th, 11th rib roasts are presented in table 6. Extremely wide variations were noted when the steers were grouped by the breeding of the sire, as the steers sired by the Shorthorn bulls had a significantly larger amount of fat than the steers sired by the five other breeds of bulls and the steers sired by the Angus bulls had significantly more fat than the four lower ranking sire groups. The steers sired by the Charolaise bulls, with an average of 22.6% fat, had significantly less fat than all other sire groups. When grouped by breed of dam, again extremely wide variations were noted, as there were significant differences among all dam groups, with the steers raised by dams of British breeding yielding considerably more fat than steers raised by Brangus and Brahman dams. These wide variations were more pronounced, of course, when the breed groups were examined where a range of 17.5 to 34.4% was found. The larger amounts of fat produced by steers of British breeding were quite apparent in these figures. The conclusion of Black *et al.* (1934) that Brahman crossbreds contained slightly less fat than Herefords and Shorthorns is in agreement with these results. Cartwright *et al.* (1958) also found that Hereford steers showed a higher percent separable fat in the 9-10-11th rib than did Hereford x Brahman steers which agrees with the general conclusions of this study that the British breeds are characterized by greater percentages of fat than are the Brahman or Charolaise breeds.

Percent Bone. The percent of bone is subject to less variation than either percent fat or percent lean, so much smaller differences were found among the percentages of bone presented in table 6. The differences between the steers of British breeding and those of Brangus, Brahman, and

TABLE 6. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PHYSICAL AND CHEMICAL SEPARATIONS AND TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS

Breed of sire	No. of steers	Physical separation (9–10–11th rib)			Chemical determinations (rib eye)		
		Percent fat	Percent bone	Percent lean	Percent fat	Percent dry fat-free lean	Percent moisture
Angus	49	29.4±.71	17.9±.33	52.7±.57	3.1±.19	25.6±.19	71.3±.12
Brahman	42	26.6±.74	18.8±.34	54.6±.60	2.1±.20	26.4±.20	71.5±.13
Brangus	43	26.4±.74	19.0±.34	55.0±.60	2.8±.20	26.2±.20	71.0±.13
Charolaise	44	22.6±.75	18.5±.35	58.5±.61	2.1±.21	26.1±.20	71.8±.13
Hereford	47	27.2±.71	17.8±.33	54.9±.58	2.4±.20	26.3±.19	71.4±.12
Shorthorn	50	31.9±.71	17.2±.33	50.9±.57	3.0±.19	26.1±.19	70.9±.12
		(S)(A)[a, b] (H,B,BA)	(BA,B,C) (B,C,A,H)	(C) (BA,H,B)	(A,S,BA) (BA,H)	(B,H,BA, C,A)(C,S,A)	(C,B) (B,H,A) (BA,S)
Breed of dam							
Angus	67	30.3±.60	17.2±.28	52.5±.48	3.3±.16	25.7±.16	71.0±.10
Brahman	70	24.4±.60	19.2±.28	56.4±.48	2.1±.16	26.4±.16	71.4±.10
Brangus	71	26.5±.58	18.6±.27	54.9±.47	2.6±.16	26.2±.15	71.2±.10
Hereford	67	28.3±.59	17.8±.27	53.9±.47	2.2±.16	26.2±.16	71.6±.10
		(A)(H) (BA)(B)	(B,BA) (H,A)	(B)(BA,H) (A)	(A) (BA,H,B)	(B,BA,H) (A)	(H,B) (B,BA) (BA,A)
Breed group							
A x A	10	32.9±1.52	16.8±.70	50.3±1.22	4.4±.42	25.2±.40	70.4±.26
A x B	18	26.1±1.13	18.6±.53	55.3±1.05	2.3±.31	26.2±.30	71.5±.24
A x BA	10	30.9±1.52	18.6±.70	50.5±1.22	3.6±.42	25.4±.40	71.0±.26
A x H	11	27.6±1.45	17.8±.67	54.6±1.17	2.1±.40	25.6±.39	72.3±.25
B x A	11	31.5±1.44	16.8±.67	51.6±1.17	3.0±.40	25.7±.38	71.3±.25
B x B	10	21.8±1.52	21.9±.70	56.3±1.22	1.3±.42	26.2±.40	72.5±.26
B x BA	10	24.6±1.51	18.7±.70	56.6±1.22	2.0±.42	26.7±.40	71.4±.26
B x H	11	28.5±1.46	17.8±.68	53.8±1.17	2.2±.40	27.0±.39	70.9±.25
BA x A	9	29.3±1.60	17.9±.75	52.7±1.29	3.7±.44	25.9±.43	70.5±.28
BA x B	13	25.7±1.33	18.2±.62	56.1±1.07	2.6±.36	26.4±.35	71.0±.23
BA x BA	10	22.3±1.52	20.4±.71	57.2±1.23	2.5±.42	26.2±.40	71.2±.26
BA x H	11	28.4±1.46	17.8±.68	53.8±1.17	2.3±.40	26.3±.39	71.4±.25
C x A	10	26.3±1.53	17.1±.71	56.6±1.23	2.7±.42	25.4±.41	71.8±.26
C x B	8	17.5±1.70	20.3±.79	62.2±1.37	1.4±.47	26.7±.45	71.9±.29
C x BA	15	20.3±1.25	19.8±.58	59.8±1.01	2.2±.34	26.0±.33	71.8±.25
C x H	11	26.1±1.47	18.5±.68	55.4±1.18	2.0±.40	26.4±.39	71.6±.25
H x A	11	28.8±1.45	18.0±.67	53.2±1.17	2.9±.40	26.1±.39	71.0±.25
H x B	13	27.2±1.33	17.7±.62	55.1±1.07	2.9±.36	26.2±.35	71.0±.23
H x BA	12	26.4±1.39	18.2±.65	55.3±1.12	1.9±.38	26.4±.37	71.7±.24
H x H	11	26.4±1.45	17.5±.67	56.1±1.17	1.8±.40	26.4±.38	71.8±.25
S x A	16	32.7±1.20	16.5±.56	50.8± .97	3.3±.33	25.6±.32	71.1±.21
S x B	8	27.8±1.70	18.9±.79	53.4±1.37	2.4±.47	26.9±.45	70.7±.29
S x BA	14	34.4±1.28	15.7±.60	49.9±1.03	3.3±.35	26.5±.34	70.2±.22
S x H	12	32.8±1.39	17.5±.65	49.7±1.12	2.9±.38	25.5±.37	71.6±.24

[a] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).

[b] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

Charolaise breeding are once again emphasized in these results, as the latter steers were ranked higher in percent bone than were the steers sired by bulls of the British breeds. Examination of the dam groups again demonstrated this fact, as the steers raised by Brahman and Brangus dams had significantly more bone than did the steers raised by Hereford and Angus cows. The lesser amount of bone among steers of British breeding is fur-

ther defined by examination of the percentages of bone among the breed groups. Black *et al.* (1934), however, found that Brahman crossbreds contained, on the average, slightly less bone than Herefords and Shorthorns.

Percent Lean. The amount of lean meat yielded by the different sire groups presented in table 6 showed wide variations. The present emphasis on increased muscling of livestock makes these figures of particular importance. Of particular note, is the fact that the steers sired by Charolaise bulls had a significantly higher percentage of lean meat than did the steers sired by any other breed of sire. The percentages of lean are naturally in direct contrast with the percentages of fat, and the Angus and Shorthorn steers, which showed large percentages of fat, ranked very low in percentage of lean. When grouped by breed of dam, these results again showed the same pattern, as the steers raised by dams of British breeding ranked lower for yield of lean meat than did the steers raised by Brahman and Brangus dams. Black *et al.* (1934) also found that Brahman crossbreds contained slightly more lean than Herefords and Shorthorns. Cartwright *et al.* (1958) found that Hereford x Brahman crossbreds contained higher percentages of separable lean in the 9-10-11th ribs than straightbred Herefords. The range of 49.7 to 62.2% in yield of lean meat found among the breed groups gives ample evidence that increases in the lean yields of beef carcasses can be made through breeding plans directed toward this goal and thus reduce the great amounts of surplus fats being produced in this country. Of course, the problem of deciding what proportion of fat and lean is most desirable in the beef carcass must be answered before the pendulum is to swing too far away from our presently accepted standards.

Chemical Determinations of Rib Eye Lean

Percent Fat. The chemical determinations yielded results that were similar to the physical separations with respect to the percent separable fat, and also with respect to marbling although some differences were noted, as seen in table 6. Steers sired by the Angus and Shorthorn bulls again ranked highest, but the steers sired by the Hereford bulls ranked lower than the steers sired by the Brangus bulls, contrary to the physical separation. The steers sired by the Brahman and Charolaise bulls yielded the lowest amounts of fat, although they were not significantly different from the steers sired by the Hereford bulls. When examined by breed of dam, the steers raised by Angus females showed a significantly greater percent of fat in the rib eye than the steers raised by the other breeds of dam. Again it was found that in the chemical determinations the steers raised by Brangus dams ranked above steers raised by Hereford dams, which was a reversal from the physical separations. The determinations of percent fat showed considerable variation among the 24 breed groups, with the straight Angus steers ranking first by a sizable amount. The straight Brahman steers and the Charolaise-Brahman steers reflected the lack of finish that was apparent in other carcass traits, while the Hereford steers

yielded a lower percent fat than was anticipated in view of the higher finish indicated by other carcass traits.

Percent Dry Fat-free Lean. The chemical determinations of dry fat-free lean in the rib eye were in general agreement with the physical separations. When ranked by sire groups as in table 6, there were no significant differences among the first five groups, while the steers sired by the Angus bulls showed a significantly lower amount of lean than did the steers sired by the Brahman, Hereford, and Brangus bulls. When ranked by breed of dam, the variation again was relatively small, although the steers raised by Angus dams had a significantly smaller percent of dry fat-free lean than the steers raised by the other three breeds of dams. The uniformity of measurements among the 24 breed groups precludes obvious patterns, but it can be seen that steers of British breeding tended to have lower amounts of dry fat-free lean than steers of Brahman breeding.

Percent Moisture. The determinations of percent moisture (table 6) were, in general, reversed in ranking from the percent fat determinations. For example, the steers sired by the Charolaise bulls, which ranked lowest with respect to percent fat, yielded the highest estimate of percent moisture, an estimate that was significantly greater than all others except that of the steers sired by Brahman bulls. The steers sired by Brahman bulls ranked fifth in percent fat and second in percent moisture. There were deviations from this pattern, particularly in the case of the steers sired by Angus bulls which ranked first in percent fat but intermediate in percent moisture. When grouped by breed of dam, the ranking for percent moisture was reversed from the ranking for percent fat with the exception of the steers raised by Hereford and Brahman dams, which were quite similar in both percent fat and percent moisture. The 24 breed groups offered no clear-cut patterns, but the uniformly high percentages of moisture among the Charolaise crosses was noticeable, as well as the high estimate of moisture of the Brahman steers.

Cooking Losses

Drip Losses. The drip losses during cooking are presented in table 7. When the steers were grouped by breed of sire it was observed that the steers sired by Shorthorn bulls had a significantly higher drip loss than any other sire group, while the steers sired by Charolaise bulls ranked lowest in drip loss. The drip losses were consistent with the percent fat shown by the physical separation, with those steers showing the largest amounts of fat also having the greatest drip losses. When grouped by breed of dam, the dam groups followed the same ranking for drip losses as they did for percent fat as determined by physical separation. The 24 bred groups showed that, in general, the steers of British breeding had greater drip losses than the steers of Brahman and Charolaise breeding, a result consistent with the percentages of fat previously shown.

Volatile Losses. The volatile losses during cooking presented in table 7

TABLE 7. LEAST SQUARES MEANS AND STANDARD ERRORS OF COOKING LOSSES AND TESTS OF SIGNIFICANCE AMONG SIRES AND DAMS

Breed of sire	No. of steers	Percent drip loss	Percent volatile loss	Percent total loss
Angus	49	4.2±.19	10.0±.26	14.2±.37
Brahman	42	3.9±.20	10.3±.27	14.2±.39
Brangus	43	3.9±.20	10.2±.27	14.1±.39
Charolaise	44	3.4±.21	10.3±.28	13.6±.40
Hereford	47	3.9±.19	10.1±.26	13.9±.37
Shorthorn	50	4.9±.19	9.6±.26	14.6±.37
		(S) (A,B,BA,H) [a, b] (B,BA,H,C)	(C,B,BA,H,A,S)	(S,A,B,BA,H,C)
Breed of dam				
Angus	67	4.6±.16	10.1±.22	14.8±.32
Brahman	70	3.4±.16	10.4±.22	13.7±.32
Brangus	71	4.0±.16	10.1±.21	14.1±.30
Hereford	67	4.1±.16	9.7±.22	13.8±.31
		(A) (H,BA) (B)	(B,A,BA) (A,BA,H)	(A,BA,H,B)
Breed group				
A x A	10	4.9±.41	10.5±.56	15.4±.80
A x B	18	3.6±.31	10.2±.42	13.8±.60
A x BA	10	4.9±.41	10.2±.56	15.1±.80
A x H	11	3.5±.40	9.2±.54	12.7±.77
B x A	11	5.1±.39	10.0±.53	15.2±.76
B x B	10	3.0±.41	11.3±.56	14.3±.80
B x BA	10	3.7±.41	10.0±.56	13.7±.80
B x H	11	3.9±.40	9.8±.54	13.7±.77
BA x A	9	4.5±.44	10.6±.59	15.1±.85
BA x B	13	3.7±.36	9.6±.49	13.3±.70
BA x BA	10	3.7±.41	11.3±.56	15.1±.80
BA x H	11	3.7±.40	9.2±.54	12.9±.77
C x A	10	3.8±.42	10.0±.56	13.8±.81
C x B	8	2.7±.46	11.1±.63	13.9±.90
C x BA	15	3.1±.34	10.4±.46	13.5±.66
C x H	11	3.8±.40	9.6±.54	13.4±.77
H x A	11	4.1±.40	9.9±.53	13.9±.77
H x B	13	3.3±.36	9.9±.49	13.2±.70
H x BA	12	3.7±.38	9.5±.51	13.2±.74
H x H	11	4.4±.39	11.0±.53	15.4±.77
S x A	16	5.3±.33	9.7±.44	15.0±.63
S x B	8	4.0±.46	10.2±.63	14.2±.90
S x BA	14	5.1±.35	9.1±.47	14.1±.68
S x H	12	5.3±.38	9.5±.51	14.8±.73

[a] The tests of significance are presented so that any two means included by the same parentheses are not significantly different, and any two means not included by the same parentheses are significantly different ($P<.05$).

[b] The abbreviations used in this paper are as follows: A=Angus; B=Brahman; BA=Brangus; C=Charolaise; H=Hereford; S=Shorthorn. The sire is presented first.

showed no significant differences when grouped by breed of sire. However, the ranking of the sire groups did indicate that steers sired by bulls of British breeding had smaller volatile losses than the steers sired by the other breeds of bulls. There was apparently a tendency for the roasts from

steers with more finish to have smaller volatile losses. When grouped by breed of dam it was found that the steers raised by Brahman dams ranked highest for volatile losses while the steers raised by Hereford dams ranked lowest. The differences were small and, in view of the relatively larger differences among these groups in drip loss, indicated that amount of finish had less influence on volatile loss than it did on drip loss. Increase in the percent moisture appeared to result in increases in volatile losses. The volatile losses of the 24 breed groups indicate that the influences of finish and percent moisture did not behave in a decisive fashion, as many deviations from expected losses were found.

Total Loss. The tendency of animals with a higher finish to have higher drip losses and lower volatile losses resulted in total cooking losses that did not vary greatly, as seen in table 7. There were no significant differences among the sire groups, although the higher ranking of the steers sired by the Shorthorn bulls indicated that the carcasses that had higher finishes also had higher total losses. When grouped by breed of dam no significant differences were found but again, the steers having the higher finish (those raised by Angus dams) also ranked first in total loss. A study of the 24 breed groups emphasized the fact that the steers sired by the Shorthorn bulls had higher total losses, but the steers sired by Hereford bulls or out of Hereford cows, showed noticeably less total cooking loss than would be expected on the basis of the percent fat determined by physical separations. Black *et al.* (1934) found that in comparisons of Brahman crossbreds to Herefords and Shorthorns, losses in cooking rib roasts were highly variable. They pointed out that great variations were frequently observed among individual roasts from cattle of the same breeding, and were of the opinion that the somewhat greater moisture content of the Hereford and Shorthorn roasts was a probable explanation of the slightly higher cooking losses.

Summary and Conclusions

An experiment was initiated in 1952 to evaluate the merits of different breeds of beef cattle and crosses among these breeds with respect to productive performance and carcass characteristics. Angus, Brahman, Brangus, Charolaise, Hereford, and Shorthorn bulls were mated to Angus, Brahman, Brangus, and Hereford cows, resulting in the production of 24 different types of cattle. This mating plan was carried out over a five-year period and produced 275 steers which were fed out on a wheat and rye grass pasture with a concentrate supplement for a 168-day period. The steers were slaughtered in the University's meats laboratory. A highly significant influence of slaughter weight on slaughter grade, carcass grade, cold dressing percent, and area of rib eye was found, so these measurements were adjusted accordingly. Analyses of slaughter grades and carcass grades yielded similar results and showed that Angus, Hereford, and Shorthorn breeding in the steers resulted in higher grades than did Brahman, Brangus,

and Charolaise breeding. However, Brahman and Brahman crossbred steers were characterized by higher cold dressing percents. The steers sired by the Charolaise bulls, which were significantly lower in carcass grade than were the other steers, ranked first in area of rib eye, although not significantly different from the steers sired by the Brangus and Angus bulls. The steers sired by the Shorthorn bulls, which ranked near the top in carcass grade ranked lowest in area of rib eye, although not significantly different from the steers sired by the Hereford and Brahman bulls. Analyses of the tenderness of the carcasses showed that steers sired by Brahman and Brangus bulls were more resistant to the shear test than were steers sired by the four other breeds of bulls, these groups receiving very similar shear values. Steers out of Brahman females also showed significantly more resistance to the shear test than did steers out of Angus, Brangus, and Hereford females. Analyses of the visual appraisal scores for carcass conformation, showed that with the exception of loin eye area, steers having Shorthorn, Hereford, and Angus breeding received higher scores than did steers having Charolaise, Brangus, and Brahman breeding. Similar results were found for carcass finish characteristics, the Charolaise steers receiving particularly low scores in this evaluation. Appraisal of carcass quality characteristics also resulted in higher scores for the steers of Shorthorn, Hereford, and Angus breeding. Physical separations showed marked differences in the fat, bone and lean constituents. The Shorthorn, Angus, and Hereford breeds showed a much greater amount of fat than did the Brahman, Brangus, and Charolaise, with the differences being reversed for the amount of bone. Steers sired by Charolaise bulls yielded a significantly greater percent of lean meat than the steers sired by the other five breeds of bulls. The steers sired by the Charolaise bulls had significantly more moisture than all other steers except those sired by the Brahman bulls, while the steers sired by Shorthorn bulls had significantly less moisture than all others except those sired by the Brangus bulls. Investigations of cooking losses revealed that the animals with a higher degree of finish had greater drip losses, and that total cooking losses appeared to be a function of both the amount of finish and the moisture content of the roast.

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CONSUMPTION OF SODIUM CHLORIDE WATER BY HEIFERS[1]

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SEVERAL years have passed since Heller (1933) published his important studies of the effects of saline and alkaline drinking waters on domestic animals. Livestock appear to be less susceptible to mineralized water than are agronomic plants. Nevertheless, there is a need for closely defining the level of various minerals in water which livestock can tolerate over extended periods without adversely affecting production. When safe maximum levels have been established, it will be possible to make recommendations concerning suitability of a mineralized water for livestock. Certain land areas may become economically useful by partially demineralizing the drinking water. The problem as related to livestock production gains importance because simple dehydration raises the level of sodium in serum, and such a serious condition probably occurs more often than is realized (Knowles, 1956). This paper reports some of the responses of growing heifers to drinking water containing 1% and 2% NaCl.

Methods

In a 3x3x2 change-over experiment, six Hereford heifers about 10 months old and averaging 481 lb. were offered drinking water containing 0, 1 and 2% of added NaCl. There were three periods of 30 days each, two animals being on a treatment during each period. The experimental design is shown in table 1.

Salt was added to tap water containing about 100 ppm. of dissolved solids. Each animal was penned individually, and feed and water consumption were recorded. The diet consisted solely of chopped alfalfa hay, *ad libitum*.

Every 10 days the heifers were weighed, rectal temperature was taken and a sample of jugular blood was obtained. Serum was separated from a portion of the blood sample. Sodium and potassium were determined by flame photometry on a protein-free filtrate of serum. For other determinations blood was drawn into heparinized tubes (0.2 mg. sodium heparinate per ml. blood). Blood specific gravity was determined by the copper sulfate method (Hawk *et al.*, 1947). Hematocrit values were determined in capillary tubes. Blood total eosinophil counts were made by the method of Speirs and Meyer (1949). Blood urea N was determined by the diacetylmonoxide method of Friedman (1953). Plasma lipids were determined by the method of Allen (1938).

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The experiment was conducted during the winter months. At the beginning of Period 3, there was a heavy snow which remained on the ground 10 days. During this time the heifers being offered 2% salt water drank little or none, but had almost normal appetites. They were observed eating snow from the ground. Therefore, Period 3 was extended 10 days, and data gathered while snow was on the ground were not considered in the results. Average maximum and minimum temperatures for Periods 1, 2 and 3 were 50° and 20°, 51° and 23°, and 58° and 27° F., respectively. Total precipitation during the experiment (excluding 10 days at beginning of Period 3) was 0.79 inches. Relative humidity was correspondingly low.

All data were subjected to analysis of variance (Snedecor, 1956) using a mixed model in which treatment was regarded as a fixed factor. Period and days-on-treatment were considered random factors. Main effects on all observations, except feed consumption, were treatment levels (0, 1, 2% NaCl), periods (first, second or third 30-day period), and days-on-

TABLE 1. EXPERIMENTAL DESIGN [a]

NaCl added to water	0%	1%	2%
Period 1	1,6	2,4	3,5
Period 2	2,5	3,6	1,4
Period 3	3,4	1,5	2,6

[a] Numbers in body of table refer to individual heifers.

treatment (10, 20, 30). Since feed weigh-backs were not made during periods, days-on-treatment was not a source of variance in feed consumption data.

Results and Discussion

The general appearance and behavior of heifers receiving 1% NaCl drinking water did not differ from those of heifers on tap water. When 2% NaCl water was offered, water consumption usually dropped sharply after the first day and feed consumption dropped. In cold weather these animals shivered. They became thin, hair became rough and the skin, especially on the muzzle, became dry and cracked. Although water consumption might be high, feces were usually very dry. When changed to 1% NaCl or tap water, the heifers appeared to recover quickly.

As shown in table 2, heifers on 1% salt water drank more than those on tap or 2% salt water. Consumption of 2% salt water approached that of tap water after the first 10 days; however, consumption of this salt water was always erratic (figure 1). Often, an animal on 2% salt water would drink none for several days and then drink over 100 lb. in a day. Hay consumption of heifers offered 1% salt water was slightly less ($P<0.05$) than that of those on tap water. Average hay consumption of heifers offered 2% salt water was only 3.8 ± 0.6 lb. daily.

Growth rate, as indicated by body weight, was not affected by drinking

TABLE 2. SUMMARY OF DATA FROM HEIFERS OFFERED SALT WATER [a]

NaCl added to water, %	0	1	2
Daily hay consumed, lb.	15.0 ± 0.73	13.8 ± 0.41	3.8 ± 0.65
Daily water consumed, lb.	52.3 ± 0.69	79.9 ± 1.31	46.3 ± 1.96
Wt. changes, lb./30 days	+39 ± 7.8	+47 ± 7.3	−81 ±10.5
Rectal temperature, ° F	103.6 ± 0.16	103.8 ± 0.17	103.0 ± 0.23
Hematocrit, vol., %	35.4 ± 0.68	36.2 ± 0.86	42.8 ± 0.93
Blood specific gravity	1.053± 0.0005	1.054± 0.0006	1.061± 0.0007
Eosinophils, mm.^{3}	280 ±19	340 ±44	470 ±71
Serum Na, mg. %	395 ±15	395 ±13	451 ±14
Serum K, mg. %	23.5 ± 1.1	24.2 ± 0.9	27.2 ± 2.2
Blood urea N, mg. %	17.79 ± 0.81	14.93 ± 0.43	12.92 ± 1.32
Plasma lipids, mg. %	171 ± 8.4	173 ± 5.6	159 ± 7.4

[a] Each datum in table is mean followed by standard error.

1% salt water. Heifers on 1% salt water lost slightly more weight than those on tap water after a 16-hour shrink period (6.02 *vs* 4.96%). The analysis of variance for weight change revealed a significant difference among the days on treatment (i.e., 10, 20, 30 days). This difference was due to the extreme weight loss of heifers during the first 10 days on 2% salt water. Weight loss on this treatment averaged 74 lb. or 14.5% of body weight in the first 10 days, as compared to an average gain of 2 lb. during

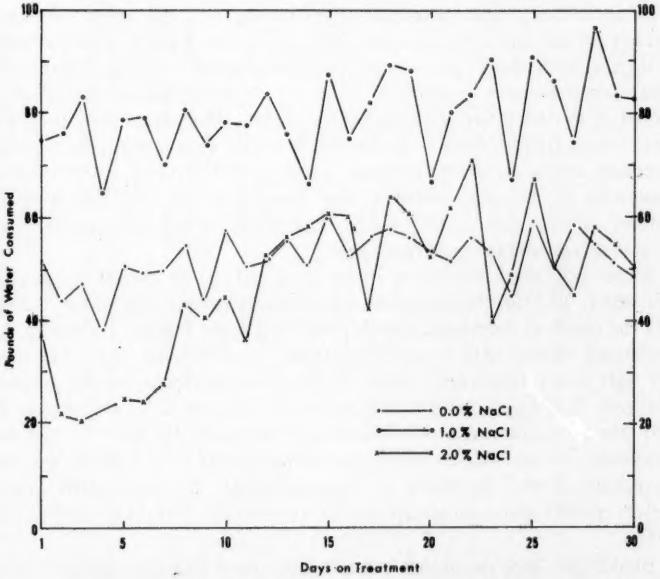

Figure 1. Average daily salt water consumption of heifers.

the second 10 days and an average loss of only 9 lb. during the third 10 days.

Rectal temperatures were lower while heifers were on 2% salt water. They were minimal (av. 102.50° F.) after 30 days on 2% salt water and were unaffected by the 1% salt water.

As indicated by the hematocrit and specific gravity data in table 2, one of the most marked symptoms of salt water toxicity was the severe hemoconcentration while heifers were drinking 2% salt water. There was a significant treatment x period interaction with blood specific gravity due to increasing specific gravity with periods on 2% salt water. There was no such trend with tap or 1% salt water.

Group differences in levels of circulating eosinophils were observed; however, interpretation is difficult because of inconsistent period differences. The severe anhydremia, as shown by increased blood specific gravity, of heifers while drinking 2% salt water may account for their higher levels of circulating eosinophils (table 2). It has been shown that the acute stress of handling and bleeding heifers causes eosinopenia (Weeth *et al.*, 1959). Also, the stress of fasting causes eosinopenia in sheep (Weeth *et al.*, 1959). The heifers drinking 2% NaCl were overtly stressed and very anorectic, yet showed no eosinopenia. It is probable that the adrenocortical response under salt water stress is different from that with a non-specific stressor, such as handling.

Serum sodium was unchanged by drinking 1% salt water; it was increased an average of 14.2% on 2% salt water. Values were as high at 10 days as at 30 days. There is no apparent reason for the significant period x days-on-treatment interaction (table 3) or the lower serum sodium observed in Period 3. By ignoring Period 3 data, the period x days-on-treatment interaction becomes insignificant. It would appear from the significant increases which occurred in serum sodium, that growing cattle could not exist long on 2% salt water. It has been reported that laboratory rats (Miller, 1957) and cattle (Heller and Paul, 1934) maintain a normal level of serum sodium until moribund.

Serum potassium tended to increase ($P<0.10$) in heifers drinking 2% salt water. The significant period x days-on-treatment interaction (table 3) was the result of decreasing serum potassium from Periods 1 through 3 and increasing values with days-on-treatment, the increase occurring on the 2% salt water treatment. After 30 days on treatment, serum potassium averaged 32.8 mg.% on 2% salt water *vs* 22.5 mg.% on tap water. Thus both serum sodium and potassium were increased by the 2% salt water treatment, serum sodium increasing rather rapidly, but serum potassium increasing slowly. It might be expected that the dehydrated, anoretic heifers would show increased serum potassium (Elkinton and Winkler, 1944).

Blood urea was decreased when heifers were drinking either 1 or 2% salt water (table 2). This effect was most apparent on 2% salt water.

TABLE 3. ANALYSIS OF VARIANCE OF DATA FROM HEIFERS OFFERED 0, 1 AND 2 PERCENT SALT WATER

		Mean squares								
Source	d.f.	Water consumption	Weight change	Rectal temperature	Blood hematocrit	Blood sp. gr.[a]	Blood eosinophils	Serum Na	Serum K	Blood urea N
Treatment (T)	2	5699.2	10447	3.08	301.70*	29.50*	178568	18774*	91.12	148.78
Period (P)	2	18.9	140	1.36	6.10	0.80	255402*	17632	248.52	8.46
Days on T (D)	2	857.4**	3470**	2.32	11.07	0.30	21391	2381	65.06	2.64
T X P	4	1558.0**	178	1.06	29.97	2.10*	96624*	2071	35.24	30.55**
T X D	4	284.9*	3370**	0.32	12.19	0.21	53521	1195	65.80	11.18
P X D	4	58.5	191	1.60*	6.72	0.55	18071	8056*	76.77*	3.40
T X P X D	8	100.1	272	0.27	9.67	0.54	14253	1267	19.09	4.35
T_0% vs. T_1%	1	6817.2**	61	0.34	6.50	0.18	41344	0	.....	73.67**
T_0% vs. T_2%	1	300.4	1806**	3.24*	503.25**	46.90**	346136**	28168**	.....	297.56**
P_1 vs. P_2	1	37.8	.....	2.67*	.....	0.64	508844**	1167	38.65	15.34
P_2 vs. P_3	1	8.9	.....	0.36	.....	0.00	101336	20401	238.19**	0.76
D_{10} vs. D_{20}	1	1145.8**	6188**	0.25	.....	.....	.....	4761	12.72	.....
D_{20} vs. D_{30}	1	13.9	230	2.45*	.....	.....	.....	1133	57.76	.....
Error	27	88.9	232	0.44	12.30	0.59	34015	2597	22.71	6.91

* $P<0.05$.
** $P<0.01$.
[a] Mean squares values are for blood specific gravity times 10^5.

The significant treatment X period interaction (table 3) was due to increasing blood urea with periods on 2% salt and decreasing values with periods on 1%. Observations of Roubicek (1959) on sheep indicate positive relationships between water consumption, urine volume and total urinary urea. Perhaps the lowered blood urea of the heifers drinking 1% salt water was due to their increased water consumption and consequent increased urination. Decreased blood urea on 2% salt water treatment may have been caused by the low alfalfa intake on this treatment.

Plasma lipids were unaffected by the treatments.

When taken off 2% salt water, the heifers usually recovered rapidly. However, on the day the experiment was concluded the animals were hauled 5 miles by truck. Feed and tap water were made available. The next morning the two heifers that had been on the 2% salt water treatment were prostrate. Their legs were rigid. They showed tetany in the neck and face, and hyperpnea. Hemoconcentration was more extreme than the previous day. Both showed eosinopenia, increased serum sodium and potassium, and decreased blood urea. The animals were treated with intravenous glucose, calcium and magnesium, and with rumen infusions of water, sucrose and skim milk. They recovered after 24 and 48 hours.

Summary

In a change-over experiment, six heifers averaging 481 lb. initial weight were supplied drinking water containing 0, 1 or 2% added NaCl for 30 days. The season was winter.

The added 1% NaCl caused a 52.8% increase in water consumption and a decrease in blood urea. No other effects were noted. This concentration of salt in the drinking water was not deleterious to growing cattle over a 30-day period.

Two percent NaCl was definitely toxic. It caused severe anorexia, weight loss and anhydremia. Animals were lethargic and rectal temperatures were lowered. Blood serum sodium was raised significantly within 10 days. Serum potassium also tended to increase. Blood urea was decreased below levels observed on tap or 1% NaCl water. Two heifers collapsed when further stressed (hauled by truck) after 30 days on 2% salt water. They showed tetany and were revived by intravenous calcium, magnesium and glucose, and by rumen infusions of water and nutrients. The eosinopenia of non-specific stressors was not seen with salt water stress.

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FARM FLOCK LAMB CREEP FEEDING TESTS [1]

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LAMB producers need more information as a basis of developing creep feeding regimes which provide an optimum relation between cost and production. In developing a creep feeding program for the farm flock, it is also necessary to evaluate feeding and management of the breeding ewes in terms of lamb gains and life-time productivity. Additional information is needed pertaining to the effects of condition of the ewes throughout the entire year upon breeding performance, lambs born, lactation, and creep response of lambs. This article summarizes four creep feeding trials conducted from 1955 to 1958. These studies investigated the effects of different creep rations and supplemental feeding of the ewe during lactation upon lamb gains.

Procedures

Trials 1 and 2. In 1955 and 1956 suckling lambs from Rambouillet, Columbia, and Hampshire ewes were used to determine the effect of adding the antibiotic, chlortetracycline, to the creep ration. The 1955 test included 63 lambs and the 1956 test, 84 lambs. Each year the ewes and lambs were stratified by breed, type of birth (single or twin), and age of lamb, and were then assigned at random to the different treatment groups. In each trial the treatments were replicated. In both trials the control ration consisted of steamed rolled barley 50%, hereafter referred to as rolled barley, rolled oats 30%, dried molasses beet pulp 10%, and cottonseed meal 10%. Alfalfa hay was fed separately.

In the first trial, one-half of the lots received antibiotic supplement [2] at a level to provide 10 mg. of chlortetracycline per pound of concentrate feed. The other half of the lots served as controls.

In the second trial, one-third of the lots received 10 mg. of chlortetracycline per pound of concentrate, one-third received 20 mg. of chlortetracycline per pound of concentrate, and one-third served as controls, receiving the basal ration only. Lambs and ewes were fed twice daily. The lambs were allowed all the concentrates they would consume between feeding periods. Any refused concentrates were weighed back before the next feeding. All the ewes were fed alfalfa hay and one pound of barley per head daily. Ewes and lambs had free access to water and a salt-bonemeal mixture. Both ewes and lambs were weighed at the beginning and

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[2] Aurofac was supplied by the Lederle Laboratory Division of the American Cyanamid Company, 30 Rockefeller Plaza, New York 20, New York.

end of the trials and all lambs were weighed at weekly intervals throughout the feeding period. Trial 1 lasted 10 weeks and trial 2 lasted 13 weeks. In trial 2 the lambs averaged approximately two weeks younger at the beginning of the trial than those in trial 1.

Data from the two tests are summarized in table 1. The average daily gains in 1955 for the supplemented and non-supplemented groups were the same (0.61 lb.). In 1956, the daily gain for the lambs receiving 10 mg., 20 mg., and 0 mg. chlortetracycline per pound of concentrate averaged 0.59, 0.57, and 0.57 lb., respectively. In both trials the differences in daily gain between the groups were not large enough to be significant.

The average daily consumption of concentrate in 1955 was 0.49 lb. for the chlortetracycline-supplemented groups and 0.44 lb. for the non-

TABLE 1. AVERAGE INITIAL WEIGHT, GAIN IN WEIGHT, AND AMOUNT OF CONCENTRATE CONSUMED BY CHLORTETRACYCLINE-SUPPLEMENTED AND NON-SUPPLEMENTED LAMBS DURING 10 AND 13 WEEK PERIODS OF TRIALS 1 AND 2

	1955—10 weeks		1956—13 weeks		
Trial and treatment	Chlortetracycline supplemented	Non-supplemented	Chlortetracycline supplemented		Non-supplemented
Levels	10 mg.	0	10 mg.	20 mg.	0
No. lambs	32	29	28	28	28
Initial weight, lb.	24.0	23.5	15.6	15.6	16.5
Final weight, lb.	67.0	66.2	69.5	68.1	68.6
Av. daily gain, lb.[a]	0.61	0.61	0.59	0.57	0.57
Daily grain consumption, lb.	0.49	0.44	0.67	0.67	0.66

[a] Differences not significant $P>0.05$.

supplemented groups. Concentrate consumption in 1956 averaged 0.67, 0.67, and 0.66 lb., respectively, for the groups receiving 10 mg., 20 mg., and 0 mg. chlortetracycline per pound of concentrate. Differences in concentrate consumption between the supplemented and unsupplemented groups were not statistically significant. In the first trial, the average daily consumption of chlortetracycline per lamb was about 1 mg. during the first week, increasing to 8.5 mg. during the seventh week, with an average of 5 mg. for the entire 10-week period. During the second test lambs that received the 10-mg. level of chlortetracycline consumed an average of 0.12 mg. chlortetracycline daily during the first week, 5.2 mg. during the sixth week, and 14.8 mg. during the thirteenth week. The average daily consumption of chlortetracycline for lambs receiving the 20-mg. level was 0.17 mg. during the first week, 8.9 mg. during the sixth week, and 31.1 mg. during the thirteenth week. The data in both trials indicate that chlortetracycline had no effect upon feed consumption and the resulting daily

gains of the lambs. The similarity of results in both trials should add confidence to conclusions drawn.

Trial 3. In 1957, the creep feeding trial stressed two objectives: (1) the comparison of single grain feeds, simple formula feeds, and more complex combinations of feeds in the creep ration; (2) the comparison of creep performance of lambs nursing ewes fed grain and ewes not fed grain during the creep feeding period.

Thirty-six Rambouillet ewes and their lambs were separated into six lots, each containing three ewes with single lambs and three with twin lambs. The six ewes and their nine lambs in each lot were assigned at random after they had been classed by weight and age. All ewes were well fleshed and in excellent physical condition at lambing time. The trial lasted 90 days. Lamb lots 1 and 2 received ration 1 which was composed of 50% rolled barley, 30% chopped oats, 10% dried molasses beet pulp,

TABLE 2. GAINS AND FEED CONSUMPTION IN CREEP TESTS COMPARING COMPLEX, SIMPLE FORMULA AND SINGLE GRAIN RATIONS IN TRIAL 3

Ration type	Complex	Rolled barley, beet pulp	Rolled barley, only
No. of lambs	18	18	18
Days on test	90	90	90
Av. initial weight, lb.	19.5	19.5	20.2
Av. final weight, lb.	73.5	76.2	70.6
Av. daily gain,[a] lb.	0.60	0.63	0.56
Daily consumption, lb.	0.83	0.83	0.66
Grain per lb. gain, lb.	1.38	1.32	1.18

[a] Significant $P<0.05$ level.

and 10% cottonseed meal. Lots 3 and 4 received ration 2 which contained 70% rolled barley and 30% dried molasses beet pulp. Lots 5 and 6 received steamed rolled barley only. In addition to the creep ration, all lambs were given free access to alfalfa hay and a mixture of bonemeal and salt in their creep.

One-half of the ewes received one pound of rolled barley daily, the other half received no grain. Thus the ewes in lots 1, 3, and 5 received one pound of rolled barley per head daily, lots 2, 4, and 6 received no grain. All ewes had free access to alfalfa hay and consumption was weighed in each lot. The lamb gains and feed consumption on the three creep rations are summarized in table 2.

Lambs receiving rolled barley and dried molasses beet pulp averaged 2.7 and 5.6 lb. heavier at the end of the trial than those receiving either the complex or the straight rolled barley ration, respectively. The complex ration containing the greater variety of feeds was higher in protein than the other rations and daily creep feed consumption was 0.83 lb. Apparently the additional protein did not stimulate gains. The average daily gain was 0.60, 0.63, and 0.56, respectively, for the complex, rolled barley-dried

molasses beet pulp, and straight rolled barley groups. The analysis of variance indicates that the ration effect was significant at the 0.05 probability level. A test of least significant difference required between means suggests that the gains of the rolled barley-molasses beet pulp group was significantly higher ($P<0.05$) than the straight barley but not between the complex and the straight barley, or the complex and rolled barley-molasses beet pulp ration. The straight rolled barley ration was economical and lambs converted it to weight efficiently, but average daily gain (0.56 lb.) and average daily consumption rate (0.66 lb.) were less than those of lambs on the other rations. Lambs fed the rolled barley gained more slowly, and daily consumption did not increase as rapidly as it did on the other rations during the last part of the trial. Lambs fed this ration

TABLE 3. EFFECTS OF GRAIN OR NO GRAIN UPON EWE MAINTENANCE OF WEIGHT, EWE FEED CONSUMPTION, AND THE CREEP CONSUMPTION AND GAIN PERFORMANCE OF THEIR LAMBS DURING THE NURSING PERIOD

Ration type	No grain	Grain, 1 lb. per ewe per day
No. of ewes	18	18
Days on test	90	90
Av. initial weight per ewe, lb.	170.1	172.1
Av. final weight per ewe, lb.	159.9	171.0
Av. loss in weight per ewe,[a] lb.	10.2	1.1
Av. daily creep feed consumption per lamb, lb.	0.79	0.79
Av. daily gain per lamb,[b] lb.	0.59	0.61
Av. daily consumption of T.D.N., lb.	2.94	3.26
Av. daily consumption of hay per ewe, lb.	5.85	4.95

[a] $P<0.01$.
[b] $P>0.05$.

had more disturbances and went "off feed" more frequently than those on the other rations.

Results obtained from feeding one pound of rolled barley per ewe per day with no grain feeding are presented in table 3. Lamb gains of the two groups were practically the same, averaging 0.61 and 0.59 lb. respectively. The ewes receiving no grain consumed 0.9 lb. more hay daily and lost 9 lb. more body weight. These differences apparently compensated for the lack of grain in the ewe ration. Apparently these ewes satisfied the milk needs of their lambs just as well as those that received grain because their lambs gained equally fast while consuming the same amount of creep feed. It appears that the increased nutrients supplied by the grain were used by the ewes to maintain their own body weight rather than to increase the gains of their lambs. The cost of supplying the grain to the ewes was $1.60 per ewe higher than where grain was not provided.

Trial 4. In 1958, rations of rolled barley and of rolled barley and dried molasses beet pulp were compared. Each group was replicated. Eight ewes

with twin lambs were assigned at random to each lot. The feeding period lasted 12 weeks.

One lamb in each treatment comparison died within the first two-week interval, leaving a total of 31 lambs per treatment. One of the lambs in the lot fed barley and beet pulp was unthrifty and gained only 14.7 lb. during the test as compared to the average gain of 47.8 lb. for the other lambs. The average total gain per lamb with this record eliminated was 45.7 lb. This lamb, however, was not removed from the lot because it was not possible to determine how much feed it had consumed. Lamb gains and feed consumption of this trial are summarized in table 4.

There were no significant differences in average total gain and daily gain between the two treatment groups. The average daily gains in this

TABLE 4. GAINS AND FEED CONSUMPTION OF LAMBS ON STEAMED ROLLED BARLEY, AND STEAMED ROLLED BARLEY-DRIED MOLASSES BEET PULP RATIONS IN TRIAL 4

Ration	Rolled barley	Rolled barley and dried molasses beet pulp
No. of lambs	31	31[a]
Av. initial weight, lb.	17.0	15.9
Av. final weight, lb.	62.2	60.6
Av. daily gain, lb.	0.54	0.53
Daily concentrate consumption, lb.	0.44	0.60
Daily roughage consumption, lb.	0.43	0.37

[a] Includes one unthrifty lamb with total gain of 14.7 lb. for entire trial.

trial were slightly smaller than in previous trials. One reason for the smaller gains is that all lambs in this test were twins whereas singles and twins were included in the other tests.

Discussion

Gains and Feed Consumption. These trials furnish useful information regarding the creep feeding and performance of suckling lambs. The feeding periods of 10–13 weeks in these tests were shorter than the time required for the lambs to reach the usual market weight. Both gain and feed consumption data are averages of the entire test. Smaller values were obtained in the first part and larger ones in the last part of the tests. The lot gains for the trials ranged from 0.53 to 0.63 lb. These gains are similar to those reported by other workers for suckling lambs of comparable ages, sex, and length of feeding period (Perry *et al.*, 1958). In all trials the lambs had access to the roughage fed the ewes; therefore, it was not possible to measure all the feed they consumed. However, the lambs had little chance to obtain any concentrate fed to the ewes and it is believed the concentrate consumption figures represent the total con-

sumed by the lambs. Average daily consumption of creep feed per lamb varied from 0.44 to 0.83 lb. among the 10 treatment lots.

Antibiotics. No increase in lamb gains or feed consumption resulted from the addition of either 10 mg. or 20 mg. of chlortetracycline per pound of creep concentrate. Hatfield *et al.* (1954) reported that in two trials suckling rations supplemented with chlortetracycline gave small but consistently higher average daily gains. Jordan and Bell (1954) and Bohman *et al.* (1955) reported no significant increase in rate of gain from the addition of chlortetracycline. From these studies it would appear that little or no increase in gains is obtained by feeding antibiotics where lambs are properly managed and kept in sanitary surroundings. This does not rule out the possibility that chlortetracycline or other antibiotics may have a beneficial effect where lambs have sub-clinical infections or may be exposed to infectious micro-organisms.

Creep Rations. Good gains were obtained from all treatments tested and the results indicate that creep rations need not be highly complex. The results also indicate that protein is not usually a limiting factor in creep rations of lambs which have access to alfalfa hay and are receiving milk from the ewes. Simple creep feeds and mixtures gave excellent results for both singles and twin lambs where high consumption was maintained. Observations in trial 3 indicated that lambs fed rolled barley only tended to develop more digestive disturbances. These lambs experienced difficulty in maintaining high levels of consumption.

Grain vs. No Grain for Ewes. Ewes receiving one pound rolled barley in addition to alfalfa hay did not produce faster gaining lambs than ewes which did not receive grain. This suggests that, where lambs are creep fed and ewes are in good condition at lambing time, lambs will gain just as fast when their mothers receive good alfalfa hay only as they will when the ewes are supplemented with grain. These results were obtained in the case of twin lambs as well as singles. Under these conditions, more profit will be realized if the grain is fed to the lambs in the creep ration. It is doubtful that the loss in weight by the ewes was detrimental. A healthy ewe in good condition should be able to lose 10–20 lb. during the winter and spring lactating season and still have time to recover adequately before the breeding season in the fall if good pastures are available. It must be pointed out that these results were obtained with healthy ewes in good condition. The success of their application in a new situation would depend upon the degree of similarity in the conditions.

Summary

Four creep feeding trials were conducted to determine the effect of certain rations and feeding practices upon lamb gains and economy of farm flock lamb fattening enterprises.

Chlortetracycline had no effect upon either feed consumption or lamb

gains when added to the creep ration at levels of 10 and 20 mg. per pound of creep concentrate.

A complex ration did not give increased lamb gains over a simple formula ration; however, rolled barley alone did not produce gains equal to either of the other two rations. Lambs receiving only rolled barley experienced difficulty in attaining and maintaining high levels of consumption. Creep fed lambs from ewes fed only alfalfa gained equally as fast as lambs from ewes fed one pound rolled barley in addition to alfalfa. Ewes fed only alfalfa consumed 0.9 lb. more alfalfa per day and lost 9.0 lb. more body weight than ewes receiving grain.

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THE EFFECT OF CHOPPING VERSUS GRINDING ON THE NUTRITIVE VALUE INDEX OF EARLY VERSUS LATE CUT RED CLOVER AND TIMOTHY HAYS [1]

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As a means of adequately describing in numerical terms the "overall" nutritional value of forages, Crampton *et al.* (1960) have proposed the use of a "Nutritive Value Index", or N.V.I. The determination of this index involves the multiplication of the "relative intake" of the forage in question by the apparent digestibility of its gross energy. (The "relative intake" of a forage is calculated by dividing the average daily voluntary intake of that forage by the expected daily intake of a "standard" forage, intake being adjusted to metabolic size of the animal). The data used as a basis for the proposal of this N.V.I. were assembled during the feeding of different species of forages chopped into lengths of 1–2 inches and of comparable stages of maturity.

On the basis of the following information, it is logical to assume that the feeding of a forage in different physical forms or of different stages of maturity will have a significant influence on its Nutritive Value Index.

The effect of grinding on the feeding value of hay has been investigated by several workers. Forbes *et al.* (1925), Olson (1930), and Mead and Goss (1935) have all found that grinding reduces the digestibility of dry matter and/or of crude fiber in various forages. Blaxter and Graham (1956) have indicated a reduction in gross energy digestibility as a result of grinding. On the other hand, Morrow and LaMaster (1929), and Swanson and Herman (1952) have reported no significant differences in the digestibility of ground and unground hay. Balch (1950), Rodrique and Allen (1956) and Blaxter *et al.* (1956) found that when ground hay was fed to ruminants it was excreted more rapidly than long or chopped hay. These later findings plus the reasoning of Crampton (1957) would imply that the grinding of a forage would bring about an increase in its voluntary intake. In fact, Meyer *et al.* (1959) suggest that fine grinding is probably the major factor causing the increased consumption of pelleted hays.

That stage of maturity of a forage influences its feeding value is well known. It has been pointed out by Crampton and Jackson (1944), Schneider *et al.* (1953), Reid *et al.* (1959) and Meyer *et al.* (1957) that a decrease in the apparent digestibility of various forage nutrients will occur as the plant matures. In addition, a decrease in voluntary intake with advancing maturity of forages has been observed by Forbes and Garrigus

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[2] Department of Nutrition.

(1950), Schneider *et al.* (1953), Smith *et al.* (1958) and Reid *et al.* (1959).

From the foregoing experimental observations, it is apparent that the two factors contributing to the derivation of a Nutritive Value Index for a forage (i.e. voluntary intake and energy digestibility) are both intimately affected by such factors as physical form in which fed and stage of maturity.

The experiment to be described represents a preliminary attempt to evaluate the significance of these factors on the N.V.I. of forages.

Experimental

The design of this experiment took the form of two consecutive "4x4 Latin Squares" in which four Cheviot ewe lambs were each fed in different rotation four artificially cured forages (viz., an early [3] and a late [4] cutting of both Red Clover and Timothy), fed in the chopped form in Square 1 and in the ground, moistened form [5] in Square 2.

TABLE 1. ANALYSIS OF FORAGES

	Timothy		Red Clover	
Fraction	Early cut	Late cut	Early cut	Late cut
Gross energy, (Cal./gm.)	4.1	4.1	4.0	4.1
Crude protein, %	7	6	14	15
Crude fiber, %	30	29	25	27
N-free extract, %	48	51	44	41
Cellulose, %	32	31	31	32
Lignin, %	9	10	10	12

The lambs were confined to digestion cages and fed each forage as the entire ration, with the exception of free access to salt, iodine, cobalt and water. To assure *ad libitum* consumption, the forages were fed at the rate of about 10% in excess of the previous day's consumption.

The feeding periods were of 21 days duration. Average daily voluntary forage intake, and body weight changes were measured over the last 14 days of each period. The final 10 days constituted the collection period for the digestibility studies. Feces collected on days 12 through 21 were apportioned to forage consumed on days 10 through 19.

Because sorting was possible with the chopped forages, weighbacks were sampled and analyzed in order to estimate the composition of the feed actually consumed. Correction of the composition of the forage, by analysis of refused feed, amounted to less than 0.5 percentage units for protein, crude fiber and cellulose and, therefore, was disregarded in the final computations. The pertinent analytical data of the two forages are shown in table 1.

[3] Early bloom (Red Clover, July 2; Timothy, July 9, 1957).
[4] Mature, seed formed (Red Clover, July 25; Timothy, July 31, 1957).
[5] Ground by means of a hammer mill fitted with a ¼-inch screen. Moistened by mixing with an equal weight of water to eliminate dust.

TABLE 2. THE EFFECT OF SPECIES, STAGE OF MATURITY AND PHYSICAL FORM OF FORAGE ON ITS RELATIVE INTAKE BY LAMBS

Forages			Relevant measurements (Each value is the mean of four observations)			
Species	Stage of maturity	Physical form	Average daily voluntary forage D.M. intake A	Metabolic size of sheep (W_{kg}·75) B	Expected standard forage intake (80×B) C	Relative intake of forage (A/C×100) D
			gm.	kg.	gm.	%
Red Clover	Early	Chopped	921	11.78	942	98
		Ground	1407	13.28	1062	132
	Late	Chopped	851	11.55	924	92
		Ground	1291	13.39	1071	120
Timothy	Early	Chopped	618	11.76	941	66
		Ground	965	13.09	1047	91
	Late	Chopped	643	11.63	930	69
		Ground	935	13.16	1053	88
	Pooled standard deviation		±143	±0.78	±62	±11

Results and Discussion

The relative intake values of early and late cut Red Clover and Timothy hays, each fed in the chopped and ground form, are given in table 2 and illustrated graphically in fig. 1. In addition, data pertinent to the determination of relative forage intake are presented in table 2, in order to illustrate the ease with which this measurement may be calculated.

It is apparent from the data in table 2 that, in all cases, the effect of grinding was to increase significantly the average daily voluntary intake of forage dry matter (column A). The range of this increase was from

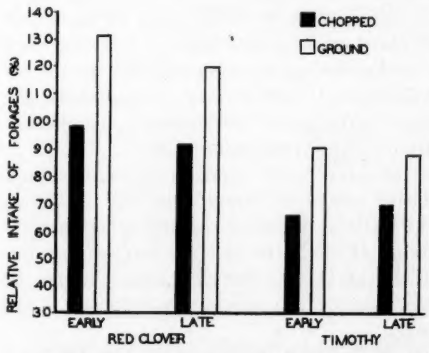

Figure 1. Graphic illustration of the effect of species, stage of maturity and physical form of forage on its relative intake by lambs.

TABLE 3. THE EFFECT OF SPECIES, STAGE OF MATURITY AND PHYSICAL FORM OF FORAGE ON ITS GROSS ENERGY DIGESTIBILITY BY LAMBS AND ON ITS NUTRITIVE VALUE INDEX

Forages			Relevant measurements (Each value is the mean of four observations)		
Species	Stage of maturity	Physical form	Relative intake of forage D	Apparent digestibility of gross energy E	Nutritive Value Index (D×E) F
			%	%	
Red Clover	Early	Chopped	98	55	54
		Ground	132	54	71
	Late	Chopped	92	53	49
		Ground	120	50	60
Timothy	Early	Chopped	66	58	38
		Ground	91	52	47
	Late	Chopped	69	50	34
		Ground	88	49	43
Pooled standard deviation			±11	±2	±5

45% in the case of late cut Timothy to 56% for early cut Timothy. At this point, it should be recalled that in the original "Latin Square" design, the chopped forages were fed to growing lambs in Square 1 and the ground forages were fed in Square 2. Consequently, the lambs consuming the ground forages were larger (see column B) and had a greater feed capacity. As a result, the increases noted in average daily voluntary intake were, in part, due to this factor. One of the advantages of calculating relative forage intake now becomes obvious. In so doing, the observed average daily voluntary intake is expressed as a percentage of the expected standard forage intake, the latter being adjusted to the metabolic size of the animal, (see columns C and D, and Crampton *et al.*, 1960). Thus, the relative forage intake, as a measurement, eliminates differences in intake resulting from differences in animal size.

Returning now to table 2, the increase in intake due to grinding, as measured by relative intake of forage, was still highly significant on a statistical basis ($P=0.01$). However, having accounted for differences in intake due to size of animals, the increase ranged now from 27% in the case of late cut Timothy to 38% for early cut Timothy. Both cuttings of Red Clover showed intermediary percentage increases in relative intake as a result of grinding.

The two stages of maturity examined in this trial did not have an appreciable influence on the relative intake of either species of forage. Late cut Red Clover, both chopped and ground, and late cut ground

Timothy all resulted in only slightly lower relative intake values than their early cut counterparts. The converse was true for early versus late cut Timothy fed in the chopped form. The overall effect of stage of maturity was as follows, and the difference was not statistically significant: Average relative intake of early cut forages, 97; of late cut forages, 92, a decrease of 5%.

An examination of the effect of species on relative forage intake indicated that, in this trial, the relative intake of Red Clover was significantly greater than that of Timothy, both for the early and late cut material and regardless of the physical form in which it was fed. The overall effect of plant species was as follows, and the difference was statistically significant ($P=0.01$): Average relative intake of Red Clover, 110; of Timothy, 78, an increase of 41%.

The gross energy digestibility values and the "Nutritive Value Indices" (N.V.I.'s) of early and late cut Red Clover and Timothy hays, each fed in the chopped and ground form, are shown in table 3. The relative intake values, given in table 2, are repeated in table 3 to illustrate the calculation of the N.V.I.'s.

The data shown in column E illustrate that, in these cases, grinding of the forages brought about only a minor reduction in gross energy digestibility. The greatest reduction was of the order of 10%, observed for the early cut Timothy.

The overall effect of the increased forage maturity was a 7% reduction in energy digestibility. The average apparent digestibility of all samples of Red Clover was essentially the same as that of all samples of Timothy. The effect of species, stage of maturity and physical form of forage on its gross energy digestibility is illustrated graphically in fig. 2.

The N.V.I.'s of all forages fed are shown in column F of table 3. As in the case of relative forage intake, the effect of grinding was to increase significantly the N.V.I.'s of all forages. Thus it is evident that the small but general decrease in energy digestibility due to grinding was more than

Figure 2. Graphic illustration of the effect of species, stage of maturity and physical form of forage on its gross energy digestibility by lambs.

Figure 3. Graphic illustration of the effect of species, stage of maturity and physical form of forage on its N.V.I.

compensated for by the large increase in relative forage intake. In this case, the 27–38% range of increase in relative intake of the ground forages was equivalent to a 22–31% range of increase in intake of digestible energy, as measured by the N.V.I.

A decrease of 9% and 13% in the N.V.I. due to increasing maturity of Timothy and Red Clover, respectively, was observed. The overall effect of stage of maturity was as follows, and the difference was just significant at the P=0.01 level: Average N.V.I. of early cut forages, 53; of late cut forages, 47, a decrease of 11%.

The large difference in relative intake due to forage species was carried through to the N.V.I. measurement. The N.V.I. of Red Clover was greater than that of Timothy, both for the early and late cut material and regardless of the physical form in which it was fed. The overall effect of plant species was as follows, and the difference was statistically significant (P=0.01); Average N.V.I. of Red Clover, 59; of Timothy, 41, an increase of 31%.

The effect of species, stage of maturity and physical form of forage on its N.V.I. is illustrated graphically in fig. 3.

The following data show the relationship between the determined N.V.I.'s and actual liveweight changes in the lambs during the final 14 days of each period.

Forage			N.V.I.	Av. daily gain (lb./day)
Red Clover	Early	Chopped	54	0.26
		Ground	71	0.49
	Late	Chopped	49	0.15
		Ground	60	0.29
Timothy	Early	Chopped	38	0.14
		Ground	47	0.25
	Late	Chopped	34	0.09
		Ground	43	0.28

The high degree of association between the N.V.I. of a forage and its animal response, as measured here by liveweight change, was confirmed by a highly significant (P=0.01) correlation coefficient of r=0.88. The effect of species, stage of maturity and physical form of forage on liveweight changes is shown graphically in fig. 4. The similarity in form between figs. 3 and 4 is striking and illustrates further the close relationship indicated above. Thus, as in the case of the data presented by Crampton *et al.* (1960), it would appear that the N.V.I. of a forage accurately reflects its effective feeding value to the animal.

In addition, the foregoing data illustrate that the categorization of forages according to species is not sufficient to obtain a true evaluation of their overall feeding value. While, in some cases, the description of forages as to species may provide a general indication of their eventual

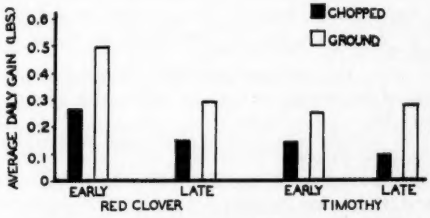

Figure 4. Graphic illustration of the effect of species, stage of maturity and physical form of forage on liveweight changes in lambs.

usefulness to the animal, various factors may influence the "within species" evaluation. For example, in these trials, it has been shown that both stage of maturity and physical form of a forage species must be considered before it can be adequately described nutritionally.

Summary

1. The physical form in which a forage was fed had a marked effect on its feeding value. When compared to chopped material, the effect of grinding a forage was to increase significantly its intake and its Nutritive Value Index, the latter being true in spite of a slight reduction in energy digestibility.

2. In this preliminary study, the stage of maturity of forage had less effect on its feeding value than physical form. A slight reduction in both intake and energy digestibility with advancing maturity contributed to a decrease in the Nutritive Value Indices of the forages—a decrease that was significant but not of the magnitude of the increase observed as a result of grinding.

3. Red Clover, at the stages of maturity and in the physical forms fed in this test, showed a significantly greater intake and Nutritive Value Index than Timothy.

4. The highly significant correlation between animal response and Nutritive Value Index confirmed the usefulness of the latter as a measure of the effective feeding value of a forage.

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A COMPARISON OF CELLULOSE DIGESTION *IN VITRO* AND *IN VIVO*

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IT seems feasible that the "artificial rumen" laboratory technique might be used in conjunction with, or substituted for, *in vivo* digestibility studies. This possibility was indicated in an initial study by Kamstra (1955), in which the 48-hour *in vitro* and *in vivo* cellulose digestion values were shown to be of similar magnitude. The comparisons, although limited in number, included a complete mixed ration, silage and forage.

As more workers report the results of *in vitro* and *in vivo* digestion comparisons, the problem is resolved into an investigation of factors which could affect the results obtained *in vitro*. Such factors include fermentation time, substrate level, inoculum and repeatability.

The present study gives the results obtained with 22 rations fed to cattle and sheep in comparisons of *in vitro* and *in vivo* cellulose digestion (LeFevre and Kamstra, 1958). The three primary purposes were: (1) to establish the *in vitro* fermentation time which would produce cellulose digestion coefficients similar to those determined *in vivo;* (2) to compare the cellulose-digesting ability of cattle and sheep inoculum *in vitro,* and (3) to determine if the concentrate to roughage ratio in the ration would have similar effects on the ability of rumen flora to digest cellulose in that ration *in vitro* and *in vivo*.

Procedure

The *in vitro* fermentation experiments for obtaining cellulose digestion coefficients were carried out according to the method of Burroughs *et al.* (1950), as modified by Bentley *et al.* (1954). The composition of the basal medium used in all the *in vitro* fermentation trials is shown in table 1.

The rumen fluid used as inoculum was obtained by suction from fistulated animals and strained through four layers of cheese cloth. Ten fistulated Rambouillet wether sheep and grade Hereford twin steers were used as sources of inoculum. The sheep received 80 gm. of rolled corn, 40 gm. of soybean oil meal, and 300 gm. of medium quality alfalfa hay twice daily. The steers were fed 800 gm. of rolled corn, 400 gm. of soybean oil meal, and 3000 gm. of medium quality alfalfa hay twice daily. Inoculum was secured before the animals received the morning feed and water. Samples of 40 ml. of the rumen inoculum were added to the fermentation

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TABLE 1. COMPOSITION OF BASAL MEDIUM FOR THE *IN VITRO* RUMEN FERMENTATION

Constituent	Grams/100 ml.
Ration	2.0
Na_2HPO_4	0.113
NaH_2PO_4	0.109
KCl	0.043
NaCl	0.043
$MgSO_4 \cdot 7H_2O$	0.01164
Na_2SO_4	0.015
$FeCl_3$	0.0044
	ml./100 ml.
Buffer (pH 6.31) [a]	15.0
Inoculum [b]	40.0

[a] Buffer composition: 5 ml., .154M $(NH_4)_2HPO_4$; 1 ml., .145M $MgSO_4$; 100 ml., .2M $NaHCO_3$.
[b] Whole rumen fluid strained through four layers of cheesecloth.

flasks after they had been gassed with CO_2 from 10 to 15 minutes and the contents of the flasks had reached 38 ± 2 C. Since this inoculum contained small plant particles in addition to rumen microorganisms, a sample was taken for cellulose analysis to correct the sample weight.

At the end of the *in vitro* digestion period, each flask was adjusted to a volume of 100 ml. Duplicate 10-ml. aliquots were taken for residual cellulose determination by the method of Crampton and Maynard (1938). The *in vitro* cellulose digestion coefficients were derived from an average of four aliquots since each trial was repeated.

For *in vivo* cellulose digestion trials, samples of feed, feces and orts were obtained from four sheep digestion trials, preliminary periods being of 15 days and collection periods of 5 days. The collection bags were attached to the animals 3 days prior to the actual collection period to allow the animals to become accustomed to the harness. All digestion trials were completed shortly before *in vitro* comparisons except in those trials with rations 17–22 (table 2). The digestion trial samples were analyzed for cellulose by the method of Crampton and Maynard (1938), and apparent digestion coefficients calculated. The *in vivo* digestion coefficients represented the average obtained with three to eight sheep.

The experimental rations (table 2) were of three main types: Alfalfa silage, alfalfa-oats mixture, and prairie hay. Penicillin, trimethyl alkylammonium stearate (Dynafac) and a product (Rufis) composed of dried rumen ingesta, animal protein with cobalt sulphate monohydrate were added to the alfalfa-oats ration. Corn, sulfuric acid and a product composed of 65% molasses dried on a corn cob base (Car-Mo-Las) were added to the alfalfa silage. The protein content of the prairie hay ration was increased to 10% by the addition of soybean oil meal.

Initial comparisons were made to establish the time necessary for *in*

vitro fermentation so the resulting cellulose digestion would be comparable to that of *in vivo* digestion. These fermentation periods ranged from 8 to 48 hours. Only digestion coefficients from 24- and 48-hour periods were used for the various comparisons in this study. The 22 rations (table 2) used for *in vivo* digestion were also used for *in vitro* fermentations.

It was desired to use both sheep and steer rumen fluids as sources of bacteria in *in vitro* fermentations. To determine their comparative value, inoculum from each was used separately in *in vitro* trials with the 22 rations (table 3). The procedure was the same in all trials, differences being in source of rumen flora.

Results and Discussion

The results from the 48-hour *in vitro* periods were similar to those of the *in vivo* trials. The 48-hour period was found satisfactory by Quicke *et al.* (1959), with little improvement by a 60-hour period. The means for 24-hour *in vitro*, 48-hour *in vitro*, and *in vivo* digestion coefficients were

TABLE 2. RATIONS USED FOR STUDIES OF CELLULOSE DIGESTION *IN VITRO* AND *IN VIVO*

Number[a, b]	Ration	Percentage cellulose
1	Alfalfa silage (no preservative added)	30.89
2	Alfalfa silage (15 lb. corn per 100 lb. fresh forage)	28.26
3	Alfalfa silage (25 lb. of 2N H_2SO_4 per ton)	31.98
4	Alfalfa silage (5 lb. Car-mo-las per lb. fresh forage)	30.92
5	75% oats, 25% alfalfa hay	17.21
6	75% oats, 25% alfalfa hay, penicillin, 10 mg. per lb.	16.97
7	75% oats, 25% alfalfa hay, Dynafac (chemobiotic) ½ gm. per lb. oats	16.89
8	75% oats, 25% alfalfa hay, Rufis (dried rumen product) ½ gm. per lb. oats	16.29
9	25% oats, 75% alfalfa hay	20.05
10	25% oats, 75% alfalfa hay, penicillin, 10 mg. per lb.	19.79
11	25% oats, 75% alfalfa hay, Dynafac (chemobiotic) 1½ gm. per lb. oats	20.02
12	25% oats, 75% alfalfa hay, Rufis (dried rumen product) 1½ gm. per. lb. oats	19.36
13	Prairie hay stored in open for one year	32.91
14	Prairie hay left in the field until May	34.29
15	Prairie hay left in the field until October	33.67
16	Prairie hay stored in barn for one year	34.81
17	Prairie hay (1947)	36.50
18	Prairie hay (1948)	35.53
19	Prairie hay (1952)	38.06
20	Prairie hay (1953—Sample 1)	34.51
21	Prairie hay (1953—Sample 2)	37.89
22	Prairie hay (1954)	36.04

[a] Rations 13 through 22—soybean oil meal added to increase protein to 10%.
[b] Rations 17 through 22—stored hay; *in vivo* digestion trials were run in 1957.

TABLE 3. *IN VITRO* AND *IN VIVO* CELLULOSE DIGESTION COEFFICIENTS

Ration[b]	*In vitro* fermentation, 24 hours[a]		*In vitro* fermentation, 48 hours[a]		Digestion trial	
	Digestion coefficient, sheep inoculum	Digestion coefficient, steer inoculum	Digestion coefficient, sheep inoculum	Digestion coefficient, steer inoculum	Sheep in trial	Digestion coefficient
1	28.9	27.0	40.4	40.0	3	51.1
2	33.1	39.3	40.9	46.8	3	60.3
3	28.9	33.0	59.0	46.5	3	61.1
4	28.6	29.9	44.6	46.7	3	48.2
5	22.0	44.8	40.5	28.7	4	34.5
6	10.4	2.6	28.8	16.7	4	31.7
7	24.4	11.2	32.3	24.3	4	27.0
8	18.4	2.0	24.9	27.1	4	29.5
9	29.8	40.3	44.8	46.5	4	47.7
10	41.7	39.1	50.0	52.2	4	46.5
11	24.8	37.5	43.0	48.0	4	46.0
12	30.1	39.4	45.1	49.6	4	45.4
13	28.8	28.9	56.4	51.8	8	59.4
14	40.8	29.0	55.3	58.9	8	56.2
15	23.6	34.3	52.4	56.0	8	55.6
16	30.1	33.7	50.0	58.4	8	58.6
17	39.5	42.3	64.6	64.4	3	26.4
18	42.1	37.0	64.9	64.7	3	37.1
19	46.9	43.2	65.5	67.3	3	47.3
20	38.1	37.3	65.6	64.6	3	40.6
21	47.4	49.7	70.9	69.6	3	51.0
22	37.0	36.2	63.8	61.8	3	47.7
Mean	31.6	30.8	50.2	49.6	..	45.9

[a] Average of two experiments, duplicate samples being run in each experiment.
[b] Rations 5 through 8, 25% oats, 75% alfalfa hay; ration 9 through 12, 75% oats, 25% alfalfa hay.

31.6, 50.2, and 45.9, respectively (table 3). There was a statistically significant difference between the 24-hour *in vitro* and *in vivo* coefficients. The correlation between the 48-hour *in vitro* and the *in vivo* coefficients was 0.307 ($P<0.05$).

In vivo and *in vitro* cellulose digestion coefficients obtained with the last six prairie hay rations, 17 through 22 as listed in table 2, showed little relationship. Each of these particular rations, all from the same digestion trial, were subjected to different periods of storage in uncovered stacks. The longest period of storage was 10 years (ration 17) and shortest, 2 years (ration 22) prior to the *in vivo* digestion trials. In addition, the samples of feed, feces and orts were stored in bottles approximately 2 years before analysis for cellulose. This may account for the different results. Without the six rations (17–22) the correlation between *in vitro* and *in vivo* coefficients was 0.841 ($P<0.01$). Hershberger *et al.* (1959) in comparing *in vitro* with *in vivo* digestion of cellulose in 35 forages, obtained a correlation coefficient of 0.97.

The results indicated very little difference between inoculum from sheep and that from cattle (table 3), means of the 22 digestion coefficients for the 24-hour fermentation period being 31.6 and 30.8, respectively, and for the 48-hour period being 50.2 and 49.6, respectively. A correlation coefficient of 0.778 was obtained with the 24-hour fermentation and 0.918 with the 48-hour fermentation ($P<0.01$). It would appear that sheep and cattle could serve interchangeably as sources of inoculum if the rations were similar.

The comparison of the digestion coefficients for rations with different concentrate to roughage ratios is shown in table 3. Rations 5, 6, 7 and 8 contained 25% roughage and rations 9, 10, 11 and 12 contained 75%. The ingredients in these rations are shown in table 2. Mean coefficients for 48-hour *in vitro* cellulose digestion were 31.6 and 45.7 ($P<0.05$) for the high and low roughage rations, respectively, when sheep rumen fluid was used as inoculum. Similarly, when steer rumen fluid was used, the coefficients means were 24.2 and 49.1 ($P<0.01$). Mean cellulose digestion coefficients obtained in digestion trials with sheep fed these rations were 30.7 for the low roughage and 46.4 for the high roughage ($P<0.01$) ration. The effect of concentrate feed (starch) upon the digestibility of cellulose has been well established, having been demonstrated by early workers and more recently by Burroughs *et al.* (1949), Swift *et al.* (1947), Arias *et al.* (1951) and Head (1953). The purpose of the present study was to determine if the effect could be demonstrated by *in vitro* fermentations as has been shown by digestion trials.

Summary

Digestibility of cellulose in 22 rations was determined by *in vivo* (conventional digestion trial) and *in vitro* methods. The 48-hour *in vitro* fermentations yielded cellulose digestion coefficients similar to the values obtained *in vivo*, the correlation coefficient for all rations being 0.397 and for 16 of them, 0.841. Cellulose digestion in 24-hour fermentations was below that obtained *in vivo* (digestion trial).

Cellulose digestion coefficients obtained *in vitro* with sheep and cattle rumen fluid as inoculum were similar. These coefficients were lower for rations containing 25% roughage than for those containing 75%. A similar effect of roughage percentage in relation to concentrate was shown in digestion trials with sheep.

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EFFECT OF PELLETING ON THE DIGESTIBILITY OF HAY BY SHEEP

P. J. Reynolds and Ivan L. Lindahl [1]

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SEVERAL studies have been conducted on the effects of pelleting on the digestibility of chopped and ground roughages or of mixed diets (Bell *et al.*, 1955; Lindahl and Davis, 1955; Long *et al.*, 1955; Blaxter and Graham, 1956; Esplin *et al.*, 1957; Meyer *et al.*, 1959; Weir *et al.*, 1959; Lindahl and Reynolds, 1959). However, no published data are available where the digestibility of long hay has been compared with the same hay in the pelleted state, when the hay was fed as the sole diet and in amounts comparable to that used in feeding practice.

Sheep normally refuse a certain amount of long hay when fed under practical conditions. The percentage of refusal depends on the quality of the hay and the level of feeding; the refused portions, in general, being the coarser stems of low digestibility. As grinding and pelleting of roughages prevents the animals from picking out and refusing the coarser portions, it seemed desirable to study the effects of pelleting on the digestibility of the nutrients in hays of varying quality.

In the experiments described below the digestibility of the nutrients in three different hays was determined for three physical states; long hay, ground hay, and pelleted hay. The digestibility of the nutrients also were calculated on two different bases, i.e., on the basis of the nutrients consumed by the sheep and on the basis of the nutrients fed to the sheep.

Experimental Procedure

Three digestion experiments were conducted in this study. In each experiment, six wethers (2 to 3 years old) were assigned at random to the columns of two 3x3 orthogonal Latin squares. Experimental diets were randomized to treatments and consecutive time periods were assigned to rows. The time periods consisted of a ten-day preliminary and ten-day collection period.

The physical states or treatments compared in each experiment were long hay, ground hay, and pelleted hay. Alfalfa hay was used in the first two experiments and second-cutting weathered grass hay in the third experiment. In each experiment the baled hay was allotted to three lots at random. One lot was reserved for feeding as long hay, one lot was ground in a hammer mill, fitted with a ½-inch screen, and the third lot

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SEVERAL studies have been conducted on the effects of pelleting on the digestibility of chopped and ground roughages or of mixed diets (Bell *et al.*, 1955; Lindahl and Davis, 1955; Long *et al.*, 1955; Blaxter and Graham, 1956; Esplin *et al.*, 1957; Meyer *et al.*, 1959; Weir *et al.*, 1959; Lindahl and Reynolds, 1959). However, no published data are available where the digestibility of long hay has been compared with the same hay in the pelleted state, when the hay was fed as the sole diet and in amounts comparable to that used in feeding practice.

Sheep normally refuse a certain amount of long hay when fed under practical conditions. The percentage of refusal depends on the quality of the hay and the level of feeding; the refused portions, in general, being the coarser stems of low digestibility. As grinding and pelleting of roughages prevents the animals from picking out and refusing the coarser portions, it seemed desirable to study the effects of pelleting on the digestibility of the nutrients in hays of varying quality.

In the experiments described below the digestibility of the nutrients in three different hays was determined for three physical states; long hay, ground hay, and pelleted hay. The digestibility of the nutrients also were calculated on two different bases, i.e., on the basis of the nutrients consumed by the sheep and on the basis of the nutrients fed to the sheep.

Experimental Procedure

Three digestion experiments were conducted in this study. In each experiment, six wethers (2 to 3 years old) were assigned at random to the columns of two 3x3 orthogonal Latin squares. Experimental diets were randomized to treatments and consecutive time periods were assigned to rows. The time periods consisted of a ten-day preliminary and ten-day collection period.

The physical states or treatments compared in each experiment were long hay, ground hay, and pelleted hay. Alfalfa hay was used in the first two experiments and second-cutting weathered grass hay in the third experiment. In each experiment the baled hay was allotted to three lots at random. One lot was reserved for feeding as long hay, one lot was ground in a hammer mill, fitted with a ½-inch screen, and the third lot

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was ground and pelleted through a 3/16-inch die. Neither steam nor water was used in pelleting of the hays.

The sheep were kept in metabolism cages which permitted freedom of movement and which had raised screen bottoms. Feed allowances were calculated to provide slightly more than maintenance requirements provided the animals consumed their daily ration. Feed was offered in equal amounts twice daily. Ten grams of salt were fed with the morning feed, and water was available at all times. Total fecal collections were made daily during the collection periods by means of waterproof canvas bags. One-half the daily feces output was taken as an aliquot, dried for 24 hours under forced draft at 55° C, and composited for the 10-day period. Composite samples of each diet were made from daily samples during the collection periods. Refused feed was weighed back each morning and was composited for analysis during the collection periods. The methods em-

TABLE 1. CHEMICAL COMPOSITION OF HAYS USED IN THE DIGESTION EXPERIMENTS [a]

Hay and expt.	Alfalfa hay, Expt. I	Alfalfa hay, Expt. II	Grass hay, Expt. III
Crude protein, %	14.7	11.5	10.4
Ether extract, %	1.4	1.1	2.8
Crude fiber, %	28.4	36.0	30.6
N-free extract, %	41.8	35.7	37.2
Gross energy (Calories/gm.)	4.01	3.99	3.87

[a] Values adjusted to 90% dry matter basis.

ployed in preparing and analyzing the feed and fecal samples have been described in a previous publication (Lindahl and Reynolds, 1959).

The digestion coefficients were calculated on two different bases, i.e., on the basis of the nutrients consumed by the sheep and on the basis of the nutrients fed. In the first case the coefficients were calculated in the usual manner, a digested nutrient being equal to the amount of nutrient actually consumed minus the amount of nutrient excreted in the feces. In calculating the digestion coefficients on the "as fed" basis, the nutrients in the refused feed were handled in the same manner as the nutrients in the excreted feces.

Results and Discussion

The chemical composition of the long hays used in the three experiments is given in table 1. The alfalfa hay used in the first experiment was considerably higher in quality than that used in the second experiment although both hays had good color.

Pelleting of the hay resulted in an increase in the ether extract and a decrease in the crude fiber content as has been observed in previous experi-

ments (Lindahl and Reynolds, 1959). The ratio of ether extract in the long hay to that in the pellets made from the hay was 1:1.16, 1:1.31 and 1:1.20, respectively, for the three experiments while the ratio of crude fiber in the long hay to that in the pellets was 1:0.93, 1:0.88 and 1:0.91.

The percentage feed refusal, as well as the crude protein and crude fiber content of the orts from the long hays, is given in table 2. The orts from experiments I and II were very fibrous which is consistent with the observation that the refused portions of the hay in these experiments consisted mainly of coarse stems. The refused hay in experiment III was hardly distinguishable from the hay as offered, but was approximately 8% higher in crude fiber and 9% lower in crude protein, than the hay as offered.

The digestion coefficients, calculated in the usual manner on the "as consumed basis" and results of tests of significance, are given in table 3.

TABLE 2. FEED REFUSAL BY SHEEP

Experiment	Hay type	Refusals			Composition of refused long hay	
		Pelleted hay	Ground hay	Long hay	Crude protein	Crude fiber
		%	%	%	%	%
I	Alfalfa	None	0.2	9.5	11.5	39.6
II	Alfalfa	None	0.8	14.6	11.2	43.0
III	Grass	None	2.4	16.2	9.5	33.1

With the exception of crude protein and ether extract, the digestion coefficients for the hay fed in the long state tended to be higher than those for the hay fed in the ground or pelleted states with the largest differences existing in the case of crude fiber. The digestibility of dry matter and crude fiber was significantly higher ($P<0.05$) for the long hay in all experiments, the digestibility of the gross energy was significantly higher in two of the three experiments and the digestibility of the N-free extract was significantly higher in one of the experiments.

These observations support the conclusion that sheep normally eat the more nutritious portions of long hay and refuse the portions of low digestibility. But when the hays are ground or pelleted the opportunities for the sheep to select certain portions of the hay are severely reduced or completely eliminated.

Differences in the digestibility of the nutrients between the ground and pelleted hays were slight except for crude fiber and ether extract. The digestibility of crude fiber was significantly lower ($P<0.05$) in two out of three trials for the pelleted hay and although the digestibility of the ether extract tended to be higher in the pelleted hay, the differences were

TABLE 3. MEANS AND TESTS OF SIGNIFICANCE AMONG MEANS WHEN DIGESTION COEFFICIENTS WERE CALCULATED ON THE "AS CONSUMED" BASIS

Constituent	Digestion coefficients for: Long hay	Ground hay	Pelleted hay	Standard errors of the means	Tests of significance[a, b]
			Experiment I—Alfalfa hay		
Dry matter	60.3	57.7	56.5	0.56	(A) (B, C)
Crude protein	67.1	68.4	68.4	0.44	(A, B, C)
Ether extract	2.7	—4.9	24.0	8.89	(A, B, C)
Crude fiber	49.3	42.6	37.5	0.45	(A) (B) (C)
N-free extract	71.4	68.5	68.1	0.73	(A) (B, C)
Gross energy	58.8	56.1	54.9	0.29	(A) (B) (C)
			Experiment II—Alfalfa hay		
Dry matter	58.6	55.1	55.0	0.61	(A) (B, C)
Crude protein	64.7	65.1	65.8	0.60	(A, B, C)
Ether extract	—6.3	19.6	22.9	3.51	(B, C) (A)
Crude fiber	48.7	38.9	36.1	0.72	(A) (B, C)
N-free extract	69.7	68.7	69.0	0.38	(A, B, C)
Gross energy	56.2	52.6	52.6	0.61	(A) (B, C)
			Experiment III—Grass hay		
Dry matter	54.1	50.0	50.0	0.34	(A) (B, C)
Crude protein	51.6	52.8	53.3	0.74	(A, B, C)
Ether extract	10.5	29.7	36.8	7.96	(B, C) (A)
Crude fiber	66.8	57.0	53.5	0.86	(A) (B) (C)
N-free extract	49.5	48.9	50.2	1.10	(A, B, C)
Gross energy	48.7	46.6	47.8	0.74	(A, B, C)

[a] A=long hay; B=ground hay; C=pellets.
[b] Any two means included by the same parentheses do no differ significantly. Any two means not included by the same parentheses do differ significantly, $P<0.05$.

not significant. These observations are in general agreement with previous work (Lindahl and Davis, 1955; Bell *et al.*, 1955; Lindahl and Reynolds, 1959).

In view of the fact that grinding and/or pelleting forced the animals to consume the coarse stemmy portions of the hays along with the portions of higher digestibility, digestion coefficients also were calculated on the basis of the nutrients present in the hays as fed to the sheep or on the "as fed" basis.

The digestion coefficients calculated on the "as fed" basis for the three experiments, and tests of significance are given in table 4. With the exception of crude fiber, the second set of coefficients tended to be higher for the nutrients in the ground or pelleted hays. The digestion coefficients for crude protein were significantly higher ($P<0.05$) in all experiments, the coefficients for N-free extract were significantly higher in two out of three experiments, and the coefficients for dry matter were significantly higher in one out of three cases.

The TDN content of the hays as affected by method of processing and calculation is given in table 5. When TDN is calculated from the conventionally determined digestion coefficients and the chemical analysis of the hays, (ignoring the nutrients in the refused feed as is often done) the TDN content of the long hay is higher than for the ground or pelleted hay in all cases. However, when TDN is calculated on the basis of the nutrients offered, the TDN content of the ground or pelleted hay is either equal to or higher than that of the long hay. The differences between the long hay and the ground or pelleted hay also became larger as the nutritive value of the hay decreased. Although the sheep refused 9.5% of the long hay in experiment I, pelleting did not increase the TDN content of the hay. In the case of the lower grade hays used in experiments II and III pelleting increased the TDN content of the hays by 9.6 and 15.1%, respectively. These observations may be interpreted that the coarse stemmy portion of the hay refused in experiment I was completely indigestible or that the inclusion of these portions by grinding or pelleting reduced the

TABLE 4. MEANS AND TESTS OF SIGNIFICANCE AMONG MEANS WHEN DIGESTION COEFFICIENTS WERE CALCULATED ON THE "AS FED" BASIS

Constituent	Digestion coefficients for: Long hay	Ground hay	Pelleted hay	Standard errors of the means	Tests of significance[a, b]
			Experiment I—Alfalfa hay		
Dry matter	54.5	57.6	56.5	0.57	(B, C) (C, A)
Crude protein	62.7	68.2	68.4	0.73	(B, C) (A)
Ether extract	2.6	—4.9	24.0	6.86	(C) (A, B)
Crude fiber	42.6	42.5	37.5	0.88	(A, B) (C)
N-free extract	66.1	68.4	68.1	0.16	(B, C) (A)
Gross energy	53.2	56.0	54.9	0.49	(B, C) (C, A)
			Experiment II—Alfalfa hay		
Dry matter	49.9	54.6	55.0	0.86	(B, C) (A)
Crude protein	56.5	64.6	65.8	0.90	(B, C) (A)
Ether extract	—4.8	19.5	22.9	3.11	(B, C) (A)
Crude fiber	40.0	38.5	36.1	0.87	(A. B, C)
N-free extract	61.1	68.1	69.0	1.10	(B, C) (A)
Gross energy	47.9	52.2	52.6	0.96	(A. B, C)
			Experiment III—Grass hay		
Dry matter	45.4	48.7	50.0	1.75	(A, B, C)
Crude protein	44.0	51.4	53.3	1.83	(B, C) (A)
Ether extract	8.1	28.9	36.8	6.66	(B, C) (A, B)
Crude fiber	56.5	55.2	53.5	1.55	(A, B, C)
N-free extract	41.1	47.7	50.2	2.36	(A, B, C)
Gross energy	40.8	45.5	47.8	1.58	(A, B, C)

[a] A=long hay; B=ground hay; C=pellets.

[b] Any two means included by the same parentheses do no differ significantly. Any two means not included by the same parentheses do differ significantly, $P<0.05$.

TABLE 5. TDN CONTENT OF HAYS ACCORDING TO METHOD OF PROCESSING AND OF CALCULATING DIGESTION COEFFICIENTS [a]

Experiment	TDN, as consumed			TDN, as fed		
	Long hay	Ground hay	Pellets	Long hay	Ground hay	Pellets
	%	%	%	%	%	%
I Alfalfa hay	53.8	49.9	49.1	49.0	49.8	49.1
II Alfalfa hay	49.9	47.0	46.8	42.7	46.6	46.8
III Grass hay	44.8	43.4	43.4	37.7	42.3	43.4

[a] Values adjusted to 90% dry matter basis.

digestibility of the total ration to an extent equal to their nutritive value. In experiment II the refused hay contributed some nutrient value when included in the total ration via processing procedures, while in experiment III the refused hay when force-fed through processing procedures was of practically the same nutritive value as the hay eaten free-choice.

A translation of the above observations to practical feeding conditions is given in table 6. This table gives the intake of TDN and digestible protein from 3 lb. of hay when fed in the three physical states. Grinding or pelleting had little or no effect on increasing the consumption of energy or protein in experiment I but did result in substantial increases in the case of the poorer grade hays used in experiments II and III. These results would suggest that the maximum benefits from grinding and pelleting would be obtained in the cases of low grade roughages or roughages of low palatability. It also would appear that the practical advantages of pelleting low grade roughages could be two-fold in nature; firstly, certain portions of the roughages that are normally refused by sheep are digested when the roughage is ground and pelleted, and secondly, pelleting increases the total consumption of the roughage as has been demonstrated in a number of feeding trials (Esplin *et al.*, 1957; Weir *et al.*, 1959; Meyer *et al.*, 1959).

Calculation of TDN in the customary manner, where the nutrients in the refused feed are ignored, could lead to the assumption that grinding and/or

TABLE 6. INTAKE OF TDN AND DIGESTIBLE PROTEIN OF ANIMALS FED THREE POUNDS OF HAY IN THE DIFFERENT PHYSICAL FORMS

Experiment	Long hay		Ground hay		Pellets	
	TDN	D.P.	TDN	D.P.	TDN	D.P.
	lb.	lb.	lb.	lb.	lb.	lb.
I Alfalfa hay	1.47	0.31	1.49	0.36	1.47	0.35
II Alfalfa hay	1.28	0.22	1.39	0.27	1.40	0.28
III Grass hay	1.13	0.15	1.27	0.19	1.30	0.19

pelleting of the hays reduced the TDN content. However, in the present series of experiments the digestibility of the gross nutrients present in the hay, as fed, was increased in two out of three experiments by grinding or pelleting. Although it has been shown that pelleting of roughage leads to increased feed consumption, and, although the question could be raised as to whether the present results are biased because of greater consumption of the processed hay, the amounts of feed offered were not excessive. The consumption of TDN when the animals received the long hays was approximately 117%, 102% and 86% of maintenance requirements for energy in the three experiments, according to the requirements given by Brody (1945). It would, therefore, appear that the experimental conditions employed in the present studies and the conclusions drawn are applicable to practical feeding conditions.

This series of experiments again raises certain questions regarding procedures for conducting digestion trials on coarse roughages and the translation of the results to practical feeding conditions. Hamilton *et al.* (1928) when working with soybean and other coarse roughages made the following statements: "Under practical conditions of feeding, animals naturally do not eat the coarse, woody, and unpalatable portions that may be found in roughages. An examination of the mangers in most any barn will substantiate this statement. . . . If, under practical conditions, a certain amount of the roughage is left uneaten, digestion coefficients based on the amounts of the nutrients offered, instead of upon the amounts of nutrients consumed, would be of considerable importance though subject to variation depending upon the condition of the feed." These workers calculated the TDN content of certain roughages and mixtures of roughages and concentrates on two bases. Using the conventional system of calculating TDN, they obtained the following TDN values for soybean hay, soybean straw and oat straw, respectively, 49.1, 35.2 and 41.7; however, when TDN was calculated on the basis of digestibility of the nutrients in the roughages as fed the values became 40.9, 23.0 and 32.4. Despite the difficulties and limitations of conducting digestion trials on the "as fed" basis, the concept of evaluating roughages on this basis appears to warrant consideration and especially so when the effects of grinding or pelleting on digestibility are being studied.

Summary

The effect of grinding and/or pelleting on the digestibility of nutrients from hay by sheep was determined at Beltsville, Maryland.

Digestibility of the gross nutrients of three different hays, which varied considerably in quality, was determined on two bases or on the "as consumed" and on the "as fed" bases. Refusal of the long hay varied from 9.5 to 16.2% although the levels of feeding were near maintenance requirements for energy. Refusal of the ground hays was very low and no refusal of pelleted hay occurred.

When the digestion coefficients were calculated on the "as consumed" basis, as is usually done in digestion trials, grinding and/or pelleting appeared to reduce digestibility of the hays. However, when digestion coefficients were calculated on the "as fed" basis either grinding and/or pelleting increased the digestibility of the nutrients and the TDN content of the two poorer quality hays.

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LATE EMBRYONIC MORTALITY AND STILLBIRTHS IN THREE BREEDS OF SWINE

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FACTORS affecting litter size in swine have been studied extensively, both from the standpoint of the number of ova produced and the degree of embryonic mortality. Baker *et al.* (1958) concluded that embryonic survival appeared to have a greater influence than ovulation rate in determining litter size.

Warwick (1928), Squiers *et al.* (1952), Perry (1954), Self *et al.* (1955), Rathnasabapathy *et al.* (1956) and Lerner *et al.* (1957) demonstrated that a major proportion of fetal mortality occurs during the early stages of gestation, ranging from 20 to 85% of the original ova shed. Most of this work involved counting corpora lutea and live fetuses on the 25th day of gestation. Rathnasabapathy *et al.* (1956) obtained a mortality of 31.3% on the 55th day and 32.8% at parturition, further substantiating that the bulk of embryonic mortality occurs during the first one-half of gestation.

The incidence and causes of stillbirths in swine have been studied less extensively. The relatively complete farrowing records kept over the years in the Cornell University swine herd allowed an appraisal of the incidence of embryonic mortality late in gestation (mummified fetuses) and of stillbirths among three breeds.

Source of Data. Farrowing records from 551 litters involving 5316 live Berkshire, Chester White and Yorkshire pigs farrowed during the period from 1946 through 1957 were used. During this period herd management was under the direction of the same swine farm manager with all breeds handled similarly. Herd health was supervised by the same veterinarian of the New York State Veterinary College. The herd was routinely vaccinated against hog cholera and swine erysipelas. Since 1940, annual herd blood tests have been negative for brucellosis. Leptospirosis has never been diagnosed in the herd, and annual herd blood tests have been negative since 1955.

Results and Discussion

The data are summarized in table 1. Sows on which litter size or live pig birth weights were not recorded are omitted. Since some mummified fetuses may not have been identified as such, the data reported here represent a conservative estimate of the actual number. No attempt was made to account for the effects of age, (Perry, 1954; Rathnasabapathy *et al.*,

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1956) season or sire on the factors studied. Effects of plane of nutrition at the time of breeding (Self *et al.*, 1955) and during early pregnancy (Self *et al.*, 1955; Gossett and Sorensen, 1959a) on litter size probably had no influence since the feeding program was the same for all three breeds.

Analysis of variance (Snedecor, 1956) using yearly mean as the experimental unit in each of the criteria considered, revealed highly significant differences ($P<0.01$) among breeds in litter size, live pig birth weight, number of mummified fetuses per litter, percentage of mummified fetuses (no. mum. fetuses/no. live + stillborn pigs + mum. fetuses), number of stillbirths per litter and percentage of stillbirths (no. of stillbirths/no. of live + stillborn pigs).

TABLE 1. SUMMARY OF FARROWING DATA FROM 1946 THROUGH 1957

Breed	Berkshire	Chester White	Yorkshire
No. of litters	162	138	251
No. of live pigs	1362	1267	2687
Av. litter size, live pigs **	8.41	9.18	10.71
Av. litter wt., lb.	24.52	24.38	26.07
Av. live pig wt., lb.**	2.92	2.66	2.44
Av. stillborn pig wt., lb.	2.48	1.74	2.12
Total no. of stillbirths	92	43	239
Av. no. stillbirths per litter **	0.57	0.33	1.03
Percentage stillborn pigs ** (stillborn/live+stillborn)	6.33	3.28	8.17
Total no. mummified fetuses	76	26	32
Av. no. mummified fetuses per litter **	0.47	0.19	0.13
Percent mummified fetuses ** (mummified fetuses/live+stillborn+ mummified fetuses)	4.97	1.95	1.08

** Highly significant difference among breeds ($P<0.01$).

The average birth weight of live pigs exceeded that of stillborn pigs in all three breeds. This agrees with the observation made by others (Carmichael and Rice, 1920; Asdell and Willman, 1941). The average litter weight showed a significant ($P<0.05$) effect of year but no effect of breed. The latter bears out the observed trend for an inverse relationship between litter size and individual pig birth weight. There were no significant effects of year on any of the other criteria considered.

Mummified fetuses represent cases where a partially resorbed shrunken, dehydrated, grey-brown conceptus was readily discernible. The size varied from a length of approximately 50 mm. to a length approaching that of a full term fetus. Distinction between a mummified fetus and a stillborn pig was made on the basis of the degree of resorption or dehydration. In the former, the sex was not readily determined. Gossett and Sorenson (1959b) indicated that normal 25-day and 40-day embryos are approximately 20 and 40 mm. long, respectively. It is therefore probable that the partially resorbed mummified fetuses reported here represented mor-

TABLE 2. RELATIONSHIP BETWEEN LITTER SIZE AND THE INCIDENCE OF MUMMIFIED FETUSES

Breed	Berkshire					Chester White					Yorkshire					
No. of mum. fetuses/litter	1	2	3	4–8		1	2	3	4–8		1	2	3	4–8		
Litter size, live pigs	No. of litters represented				Total	No. of litters represented				Total	No. of litters represented				Total	Grand total
1–5	3	1	0	3	7	0	0	2	1	3	1	0	0	0	1	11
6	2	0	2	1	5	0	0	0	0	0	3	1	0	0	4	9
7	1	0	1	1	3	0	0	0	0	0	0	0	0	0	0	3
8	2	0	0	0	2	1	0	0	0	1	0	0	0	0	0	3
9	4	1	1	0	6	2	0	0	0	2	1	0	1	0	2	10
10	2	3	1	0	6	1	0	0	0	1	2	0	0	0	2	9
11	2	1	0	0	3	1	1	0	0	2	3	1	1	0	5	10
12–16	1	0	0	0	1	6	1	0	0	7	5	2	0	0	7	15
Total	17	6	5	5	33	11	2	2	1	16	15	4	2	0	21	70

TABLE 3. RELATIONSHIP BETWEEN LITTER SIZE AND THE INCIDENCE OF STILLBIRTHS

Breed	Berkshire					Chester White					Yorkshire					
No. of stillbirths/litter	1	2	3	4–7		1	2	3	4–7		1	2	3	4–7		
Litter size, live pigs	No. of litters represented				Total	No. of litters represented				Total	No. of litters represented				Total	Grand total
1–5	3	0	0	1	4	3	3	1	0	7	1	0	1	1	3	14
6	2	3	0	0	5	1	0	0	0	1	1	0	1	1	3	9
7	1	1	2	0	4	0	0	0	0	0	0	0	1	0	1	5
8	3	2	2	0	7	3	0	0	0	3	5	2	1	0	8	18
9	7	4	1	2	14	3	2	1	0	6	11	4	4	0	19	39
10	9	4	0	0	13	1	2	0	0	3	11	6	4	2	23	39
11	6	1	0	0	7	1	0	0	0	1	10	5	4	3	22	30
12–17	1	1	0	0	2	7	2	0	0	9	33	12	6	3	54	65
Total	32	16	5	3	56	19	9	2	0	30	72	29	22	10	133	219

tality which occurred after the 40th day of gestation. The higher percentage of mummified fetuses found in the Berkshire sows in this study accounts, in part, for the smaller litter size than in the other breeds and agrees with the concept of genetic differences in prenatal mortality (Lerner *et al.*, 1957; Baker *et al.*, 1958.) The theory proposed by Perry (1954) that early embryonic mortality may be greater in large litters due to an excess of progesterone output by the larger number of corpora lutea apparently does not apply in cases of late embryonic mortality, since the Berkshire breed in this study had the smallest average litter size but the highest percentage of mummified fetuses. Breed differences could exist, of course, in the amount of progesterone secreted per corpus luteum. Exogenous progesterone given early in gestation as a means of decreasing embryonic mortality has produced variable results (Reddy *et al.*, 1958; Spies *et al.*, 1959).

Table 2 summarizes the relationship between litter size and incidence of mummified fetuses for each of the three breeds. Single mummified fetuses occurred most frequently. They were more prevalent in large than in small litters in the Chester White and Yorkshire breeds. Litters containing more than three mummified fetuses in the Berkshire breed were associated with a small number of living pigs.

Table 3 summarizes the relationship between litter size and the incidence of stillbirths. The tendency for the incidence of stillbirths to increase with larger litters as reported by Carmichael and Rice (1920) and by Asdell and Willman (1941) was also observed here. Single stillbirths were the most frequent.

The frequency of simultaneous occurrence of stillbirths and mummified fetuses was checked to determine whether the presence of mummified fetuses had an influence on stillbirths. Only 29 out of the 70 litters that contained mummified fetuses also contained stillbirths. Furthermore, only 31 out of 219 litters that contained stillbirths contained mummified fetuses. These observations indicate no causative relationship in this regard.

Summary

The farrowing records of purebred litters from Berkshire, Chester White and Yorkshire sows for the 12-year period 1946–57 were examined.

Highly significant breed differences ($P<0.01$) were found in average litter size, average live-pig birth weight, average number of mummified fetuses per litter, percentage of mummified fetuses, average number of stillborn pigs per litter and percentage of stillborn pigs. The average birth weight of live pigs exceeded that of stillborn pigs in all three breeds. The average litter weight was not statistically different among breeds. There was a significant ($P<0.05$) effect of year on average litter weight, but not on any of the other criteria considered.

Single mummified fetuses occurred more frequently than two or more in a litter. Mummified fetuses were more prevalent in large than in small

litters in the Chester White and Yorkshire breeds. The incidence of stillbirths increased with increasing litter size. The presence of mummified fetuses did not seem to be related to the occurrence of stillbirths.

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SOME EFFECTS OF DIETARY LEVELS OF PROTEIN AND ALFALFA MEAL AND OF ANTIBIOTIC SUPPLEMENTATION ON GROWTH, FEED EFFICIENCY AND CARCASS CHARACTERISTICS IN SWINE [1]

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THE declining demand for lard and the increasing consumer resistance to excess fat in pork products have been major factors in reducing both per capita consumption and the share of consumers' income spent for pork. This trend emphasizes the importance of measuring the effects of diet on carcass characteristics in swine. Such information should contribute to the formulation of diets designed to promote maximum rate and efficiency of gains consistent with high carcass quality.

Forbes (1909) was among the earliest to report on the ability of dietary factors to influence carcass composition in swine. Since no surplus fat problem existed at that time there was little incentive for attempting to modify the ratio of fat and lean in pork, and indeed, research efforts in this field for the next two decades were largely devoted to quality of fat, as exemplified by the "soft-pork investigations" conducted jointly by the U.S.D.A. and some ten or twelve state agricultural experiment stations (Hankins and Ellis, 1926). The decline in demand for lard, research on comparative merits of different types of hogs, and investigations of dietary factors in relation to growth, efficiency and carcass characteristics are generally considered to have begun about the mid 1920's. Among the important contributions of the next 15 years were the findings of Hogan *et al.* (1925), Ferrin and McCarty (1928), Saint Pierre *et al.* (1934), Ellis and Zeller (1934), Ellis and Hankins (1935), Freeman (1935), Carroll and Burroughs (1935), Keith and Miller (1939) and Robison (1940) culminating in the classical experiments of McMeekan (1940, 1941) who demonstrated the effects of high and low planes of nutrition on swine during both early and later stages of growth.

A number of recent studies have dealt with the effects of varying levels of protein and crude fiber, and of antibiotic supplementation of swine diets, on rate, efficiency, and character of growth of market hogs. This report presents further experimental evidence on the influence of these variables in producing desirable swine carcasses.

Experimental

Two preliminary trials which included three variables; protein, crude fiber, and antibiotic supplementation were reported by Stevenson *et al.*

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(1955). Two subsequent experiments were then conducted to obtain more specific information on these three factors. The effect of varying the fiber content of diets by the use of different levels of dehydrated alfalfa meal was studied in experiment I and a comparison of two protein levels with and without chlortetracycline was made in experiment II.

Experiment I. In this experiment all test pigs received a diet which contained 4% dehydrated alfalfa meal and had a protein content calculated at 18% from 56 days of age until they individually reached 100 lb. (±5 lb.) live weight. At this weight all pigs received diets calculated to contain 16% protein but varying in alfalfa content as follows: Lots 1 and 2, 4% alfalfa; Lots 3 and 4, 16% and 28% alfalfa respectively; Lots 5 and

TABLE 1. OUTLINE OF TREATMENT VARIABLES

	Lot							
Weight interval (lb.)	1	2	3	4	5	6	7	8
	Experiment I							
	Alfalfa meal in diet (%)							
Weaning–100	4	4	4	4	4	4	4	4
100–125	4	4	16	28	4	4	4	4
125–150	4	4	16	28	16	28	4	4
150–225	4	4	16	28	16	28	16	28
	Experiment II							
	Protein level (%) and Antibiotic (+, −)							
Weaning–125	14−	14−	14+	14+	18−	18−	18+	18+
125–225	11−	11+	11−	11+	15−	15+	15−	15+

6, 4% alfalfa until they individually reached 125 lb. (±5 lb.) at which weight they were changed to the 16% and 28% alfalfa levels; and lots 7 and 8 similarly changed from 4% to 16% and 28% alfalfa, respectively, as they individually reached 150 lb. (±5 lb.) live weight. Forty-eight crossbred weanling pigs were randomized to eight treatments by outcome groups in each of the two trials. Due to a lack of litters of required size and uniformity, outcome groups were based on similarity of rate of gain previous to introduction of treatment variables, in the first trial. However, litter outcome groups were available for the second trial. Data from this experiment are given in table 3, and mean squares from the analysis of variance in table 5.

Because of the experimental design (table 1) only experimental groups 3 through 8 could be used in an orthogonal analysis. These groups provided a comparison between the 16 and 28% alfalfa levels, the three weights at which the pigs went on these levels (time), and the interaction between levels and time (see table 4, Experiment I and lines C and D under the column "sources of variation"). The remaining two degrees of

freedom for treatment were assigned to the non-orthogonal comparisons between the controls and the 16 or 28% alfalfa treatments. The adjustment for sex differences was made by use of covariance, because unequal division of sexes within the experimental groups prevented a simple determination of the variance due to sex in the analysis of variance.

Experiment II. This experiment, consisting of a summer trial, a winter trial, and a second summer trial, compared two levels of protein (14% vs. 18% subsequently reduced to 11% vs. 15% when all pigs on test averaged approximately 125 lb. live weight), and presence or absence of a chlortetracycline-vitamin B_{12} supplement in the diet during the two stages of the growing-fattening period. Each trial utilized 48 crossbred weanling pigs randomized to eight treatments (2^3 factorial design) from litter outcome

TABLE 2. BASAL DIET USED IN BOTH EXPERIMENTS

Ingredient	Percent
Yellow corn meal	80.2
Soybean oil meal	7.4
Digester tankage	7.4
Dehydrated alfalfa meal	4.0
Mineral mixture[b]	1.0
Aurofac[c]	0.0

[a] Proportions of corn, alfalfa and protein concentrates were changed to give the prescribed dietary variables.

[b] Ground limestone, 32.0%; steamed bonemeal, 31.9%; iodized salt, 30.6%; magnesium sulfate, 2.5%; ferrous sulfate, 2.1%; cupric sulfate, 0.2%; manganous sulfate, 0.5%; cobaltous sulfate, 0.1% and zinc oxide 0.1%.

[c] In supplemented diets, 0.3% Aurofac replaced an equal amount of corn. It supplied 5.4 mg. chlortetracycline and 5.4 mcg. vitamin B_{12} per pound of diet.

groups. The data and mean squares from the statistical analyses for this experiment are given in tables 4 and 5.

Except for the differences previously described, experimental procedures were standardized and alike in both experiments. All pigs were allowed to eat *ad libitum* in concrete-floored pens with access to outside paddocks also floored with concrete; these quarters were cleaned daily. Pigs were individually removed from the feeding trials at approximately 225 lb. live weight and kept without feed for 24 hours before slaughter. Slaughtering and cutting were done as described by Hankins and Hiner (1937) and Hiner (1949). In addition to detailed carcass measurements, the right hams were chemically analyzed for content of moisture, protein, fat and ash. A summary of experimental treatments is presented in table 1. The control diet shown in table 2 is a sample of the type of diet used in these studies.

Results and Discussion

Experiment I. Data from the two trials in Experiment I provide a basis for comparison of: (1) sex differences, (2) seasonal effects, (3) effects of

different levels of alfalfa, and (4) effects of increasing fiber level (as alfalfa) at different body weight intervals. In the comparison between sexes, gilts gained weight less rapidly, had less thickness of bacon and of backfat and less total carcass fat than their barrow littermates, but exceeded the barrows in carcass length and in the yield of five preferred cuts expressed as percentage of slaughter weight. All of these sex differences except rate of gain were significant at the 1% level (see table 5 for statistical data).

Since the trials were replicates the seasonal effects included differences between replicates. However, the animals in these trials were closely related, and indeed the results were in close agreement with the usual differences observed between summer and winter feeding trials. Pigs on the winter trial ate more feed per day, gained weight faster, required more feed per pound of gain and had thicker bacon and backfat than summer fed pigs, all by significant amounts ($P<.05$), and the percentage of the five preferred cuts was greater for the winter-fed pigs by a highly significant amount ($P<.01$). No difference between seasons was found for lean to fat ratio in the ham. In line with the tendency toward a leaner type carcass for the summer-fed animals the carcass length of those pigs was significantly longer ($P<.01$).

The moderate increase in alfalfa content (from 4% to 16%) tended to modify the factors observed in the same direction as did the increase in alfalfa content to 28%, but the changes were not as great nor as consistent. Growth rate was depressed, bacon thickness decreased and carcass length increased by significant amounts at the 16% alfalfa level. Further differences characteristic of a leaner carcass were observed when the highest alfalfa level (28%) was fed. Dressing percent, backfat and bacon thickness and total fat percent were all significantly decreased although carcass length was only slightly affected by the additional alfalfa. Data obtained from physical separation and chemical analysis of the total edible portion of the hams from these pigs (28% alfalfa) showed a consistently higher proportion of lean tissue compared to those on either the 16 or 4% alfalfa levels. On the debit side, of course, was the additional decrease in rate and efficiency of gain although daily feed intake remained the same.

The second variable in this experiment, the pig weight at which the increments of alfalfa were added had little effect on any of the factors considered. The only items that showed any significant changes were carcass grade and length of carcass, both differences indicating a leaner carcass from pigs receiving the added alfalfa at 150 lb. weight. The statistical analysis employed did not include a direct comparison of the weight groups with the controls on the 4% alfalfa. As inspection of the averages (table 3) shows that in many cases there were marked differences between the control average and those from the various weight groups. In almost all cases, as would be expected, raising the alfalfa percentage in the diet promoted characteristics considered desirable in a meat type carcass. Particularly noticeable were the measurements for (1) backfat thickness which aver-

TABLE 3. AVERAGES OF DATA FROM EXPERIMENT I

Item	Comparisons									
	Trial		Sex		Diet variables					
						Alfalfa level (%)		Weight alfalfa increments added (lb.)		
	1	2	♂	♀	Control	16	28	100	125	150
Pigs,[a] no.	46	48	43	51	22	36	36	24	24	24
ADG, lb.	1.48	1.56	1.58	1.48	1.65	1.55	1.40	1.48	1.50	1.45
AD feed, lb.	6.1	7.0	.....	.....	6.6	6.5	6.5	6.7	6.5	6.2
Feed/cwt, lb.	421	445	.....	.....	412	421	458	456	436	427
Carcass grade[b]	8.0	7.5	7.2	8.3	7.5	7.6	8.2	7.8	7.8	8.2
Dressing percent, %	80.0	80.4	80.2	80.2	80.9	80.5	79.5	80.0	79.7	80.2
Back fat,[c] in.	1.51	1.58	1.65	1.46	1.64	1.58	1.45	1.53	1.54	1.48
All fat, %	12.9	12.9	13.7	12.2	13.6	13.3	12.0	12.6	12.7	12.7
Five preferred cuts, %	50.6	51.1	50.2	51.4	51.0	50.8	50.9	51.1	50.4	51.1
Bacon thickness,[c] in.	2.32	2.41	2.44	2.30	2.46	2.37	2.29	2.34	2.36	2.28
Carcass length,[c] in.	31.1	30.5	30.4	31.0	30.4	30.8	31.0	30.9	30.6	31.2
Ham analysis:										
Physical										
Lean, %	56.0	56.3	54.8	55.7	55.3	55.7	57.1	57.0	56.1	56.2
Fat, %	29.8	30.7	31.8	28.9	31.1	30.7	29.2	29.2	30.1	30.4
Chemical										
Water, %	52.2	51.1	50.7	52.4	51.1	51.2	52.4	52.3	51.5	51.6
Protein,[d] %	33.1	32.5	31.4	34.0	31.9	32.1	34.0	33.7	32.8	32.6
Ether extract,[d] %	65.3	65.8	66.9	64.4	66.6	66.2	64.1	64.6	65.5	65.5

[a] Two pigs were removed from test in trial 1. All averages and statistical analyses were computed using missing values calculated according to the method of Snedecor (1946) p. 268.

[b] Carcass grades were coded for computation as follows: 9=1+; 8=1; 7=1—; 6=2+; 5=2; 4=2—.

[c] Raw data in millimeters.

[d] Percent of dry matter of total edible portion of ham.

aged 1.64 inches for pigs getting 4% alfalfa while supplemented ones averaged only 1.52 inches and (2) bacon thickness where measurements of 2.46 and 2.33 inches were obtained for unsupplemented and supplemented pigs, respectively.

The data on physical separation and chemical analysis of the hams were in agreement with such carcass measurements as fat percentage, backfat thickness and bacon thickness. The amount of separable lean and percentage of protein of the ham increased with level of alfalfa but decreased slightly when the addition was made at 125 or 150 lb. Although a significantly higher amount of moisture was found in the edible portion of the hams from the 28% alfalfa group, the protein content (dry matter basis) of these hams was also significantly higher than it was in hams from either the 4 or 16% treatments.

The results of this experiment are in substantial agreement with those reported recently by other workers (Bohman *et al.*, 1955 and Merkel *et al.*, 1958a, b). Becker *et al.* (1956) also showed that equalizing the TDN in rations containing 20 or 30% alfalfa by adding corn oil improved feed efficiency and rate of gain. The evidence certainly shows that the use of high fiber rations presents one of the simplest methods of controlling the type of hog carcass produced. From the data obtained in this experiment a level of alfalfa between 16 and 28% added between 125 and 150 lb. live weight would seem to give the best results with respect to both feed lot performance and quality of carcass produced.

Experiment II. The three trials in experiment II were conducted over a period of three seasons. Pigs used in trial 3 in the summer of 1955 and trial 4 the following winter were the offspring of the same group of sows and boars and thus of similar genetic makeup. Pigs in trial 5 were from another generation of sows and sired by purebred Yorkshire boars in contrast to the Beltsville No. 1 breeding of the sires in trials 3 and 4. These remarks are presented in order more fully to explain the data presented in table 4. Table 4 also shows that several pigs were lost during the course of each trial. These losses were not explainable on the basis of experimental treatment, although more pigs were lost from groups receiving no antibiotic during the first half of the experiment (13), than were lost from supplemented groups (6). Because of these missing data, the statistical analyses for this experiment were based on lot means rather than on individual values. The resulting mean squares from these analyses are given in table 5. Despite the reduction in degrees of freedom, many differences were large enough to be statistically significant. The data in table 4 show that the largest source of between trial differences, especially with respect to carcass characteristics, was the difference in results between trial 5 and trials 3 and 4, presumably because of variation in the breeding of the pigs on these experiments. The only items that were not influenced strongly by this difference in breeding were rate of gain and bacon thickness.

The effects of treatment on feed lot performance were not great. The

TABLE 4. AVERAGES OF DATA FROM EXPERIMENT II

Item	Comparisons								
	Trial			Diet variables					
				Protein		Antibiotic I		Antibiotic II	
	3	4	5	High	Low	+	−	+	−
Pigs, no.	39	43	43	66	59	66	59	61	64
ADG, lb.	1.46	1.53	1.56	1.54	1.50	1.54	1.49	1.51	1.52
AD Feed, lb.	4.9	5.6	5.1	5.3	5.1	5.3	5.0	5.1	5.2
Feed/Cwt, lb.	370	381	353	359	377	364	372	369	367
Carcass grade[a]	6.7	6.8	7.4	7.3	6.6	7.1	6.8	6.9	7.0
Dressing percent, %	80.5	81.0	79.8	80.4	80.5	80.5	80.5	80.6	80.4
Backfat,[b] in.	1.74	1.77	1.65	1.68	1.78	1.69	1.76	1.73	1.72
All fat, %	15.1	15.1	14.3	14.2	15.6	14.7	14.9	14.8	14.9
Five preferred cuts, %	49.7	50.3	49.2	50.1	49.3	49.8	49.6	49.8	49.7
Bacon thickness,[b] in.	2.49	2.52	2.44	2.47	2.50	2.48	2.48	2.49	2.48
Carcass length,[b] in.	30.3	30.2	31.1	30.7	30.4	30.4	30.6	30.5	30.6
Ham analysis:									
Physical									
Lean, %	52.4	53.4	56.8	55.5	52.8	54.4	54.0	54.5	53.9
Fat, %	33.9	33.4	28.8	30.5	33.5	31.8	32.3	31.6	32.4
Chemical									
Water, %	48.6	49.0	....	50.2	47.4	49.1	48.5	49.1	48.5
Protein,[c] %	28.4	30.1	....	31.2	27.2	29.6	28.9	30.2	28.5
Ether extract,[c] %	69.9	68.5	....	67.1	71.3	68.7	69.7	68.4	70.0

[a] Carcass grades coded for computation as follows: 9=1+; 8=1; 7=1−; 6=2+; 5=2; 4=2−.
[b] Raw data in millimeters.
[c] Percent of dry matter of total edible portion of ham.

TABLE 5. MEAN SQUARES

Source of variation	df	ADG	AD feed	Feed per cwt.	Carcass grade	Dressing percent	Ham analysis: Back fat	All fat	Five preferred cuts	Bacon thickness	Carcass length	Ham analysis: Physical: Lean	Ham analysis: Physical: Fat	Ham analysis: Chemical: Water	Ham analysis: Chemical: Protein	Ham analysis: Chemical: Ether extract
Experiment I[a]																
Trials	1	.1320*	2.72**	2304*	3.00*	3.63*	51.39*	0.51	9.77**	86.69*	47.31**	5.47	16.03	25.56	4.73	3.65
Treatments	7	.1747*	0.23	1249*	1.71*	5.88**	63.50**	6.60**	1.39	42.92**	8.17*	11.00	11.83	7.82	18.94	23.51
(A) 4 vs. 16% alfalfa	1	.1403*	0.08	225	1.00	1.88	21.04	0.01	1.39	55.01*	68.25**	2.80	0.17	0	0.03	0.36
(B) 4 vs. 28% alfalfa	1	.9057**	0.11	14017**	4.00**	27.21**	279.78**	27.62**	0.37	212.11**	26.10**	34.69*	40.41*	19.76	49.86*	76.99**
(C) 16 vs. 28% alfalfa	1	.4160**	0	4107**	0.50	18.56**	196.01**	32.78**	0.41	65.54*	2.10	35.58*	43.74*	30.37*	64.28*	83.40**
(D) Time	2	.0044	0.22	920	2.00*	1.25	10.70	0.53	1.48	16.91	10.45*	3.55	8.64	3.24	7.02	4.74
C x D	2	.0547	0.47	191	0	0.46	39.59*	1.48	0.02	5.83	0.88	0.58	2.41	2.97	14.64	15.57
Outcome groups within trials	10	.0647*	....	...	0.80	3.49**	13.54	3.35**	1.27	27.82*	3.71	21.30**	19.17*	19.12**	33.62**	36.78**
Trials x treatments	7	.0100	0.07	207	1.14	0.35	6.76	0.59	0.43	16.38	2.92	5.25	5.21	6.06	4.97	5.05
Reduction of variance due to sex	1	.0857	....	...	25.82**	0.11	326.88**	44.44**	21.70**	327.84**	25.82**	72.71**	94.33**	23.44	68.88	50.99*
Error	67	.0255	....	...	0.55	0.91	9.35	1.25	0.88	13.75	3.25	7.98	9.24	6.52	9.21	10.91
Experiment II[b]																
Trials	2	.0138	0.90**	1603*	1.18**	2.90**	18.58**	1.91*	2.54**	9.10	11.49**	42.43**	62.03**	0.64	3.20	7.73
Treatments	7	.0044	0.35**	398	0.72**	0.18	9.94**	2.40**	0.79**	4.76	1.25	10.99*	14.63**	6.32*	11.25*	13.50*
(A) Protein level	1	.0074	0.15	1999*	2.47**	0	38.00**	13.35**	4.59**	4.34	2.81	43.74**	54.60**	33.06**	55.05**	68.39**
(B) Antibiotic I	1	.0122	0.45*	409	0.40	0	23.60**	0.85	0.40	0.01	1.50	1.04	1.82	1.44	0.19	3.78
(C) Antibiotic II	1	.0008	0.12	22	0.05	0.24	2.04	0.01	0.05	0.67	0.43	2.16	4.00	1.44	6.96	10.73
A x B	1	.0047	0.85**	39	0.58	0.17	2.16	0.22	0.07	5.60	0.16	1.22	1.21	0.20	2.89	1.96
A x C	1	.0048	0.12	135	0.45	0.01	0.81	0.58	0.01	2.40	2.66	3.84	5.81	3.42	2.37	0.15
B x C	1	.0008	0.77**	145	1.08*	0.74	2.94	1.64	0.35	9.37	0.88	15.04*	20.53*	2.56	13.06*	9.45
Error	14	.0102	0.07	373	0.14	0.35	2.12	0.34	0.16	4.95	0.94	2.76	3.05	1.40	2.10	2.03

[a] Mean squares adjusted for sex differences.
[b] Mean squares computed from lot averages.

difference in protein level had no effect on rate of gain or daily feed consumption, but the high protein level produced a 5% improvement in feed efficiency. There was a small but nonsignificant increase in rate of gain and feed efficiency resulting from antibiotic addition up to 125 lb., and no effect from the antibiotic in the second half of the experiment. A significant decrease in daily feed intake was found when antibiotics were omitted in the period from weaning to 125 lb. These results of high protein feeding are similar to those reported by Tribble *et al.* (1956), although these workers reported more pronounced effects from antibiotics.

The difference in protein level caused the only consistent effects on various carcass characteristics studied. Backfat thickness was reduced 6% and fat of the carcass by 10% in the high protein treatment ($P<.01$), while there was a highly significant increase in percentage of preferred cuts from pigs on this treatment. The data on physical separation and chemical analyses also showed the effect of the high protein level on the reduction of carcass fat content. Antibiotic supplementation in either the first or second period of the experiments had no great effect except the highly significant reduction in backfat thickness for antibiotic supplemented pigs in period I.

It was interesting to note that several items showed a significant interaction between the two antibiotic periods (table 5). These significant interactions for carcass grade, all fat percent, percent of physically separated lean and percent protein in the ham appeared, from inspection of the averages, to be due to the higher fat content of the carcasses in the two lots per trial which received no antibiotic. Thus although antibiotic addition did not produce any great differences in the individual items examined, their overall effect was to reduce the quantity of fat produced, presumably through the stimulation of growth during the early part of the experimental period.

The results of this experiment show that a protein level of 18% reduced to 15% at 125 lb. can have a definite effect on reducing the fatness of the resulting carcass when compared to a protein level of 14% reduced to 11% at 125 lb. Less pronounced but still consistent effects on rate of gain and feed efficiency are also found in favor of the high protein level. The addition of chlortetracycline to the diet seems to be of little importance as far as any effects on the resulting carcass are concerned.

Summary

Three levels of dehydrated alfalfa meal (experiment I) and two levels of protein with or without chlortetracycline (experiment II) were studied in a series of five trials to determine effects on feed lot performance and carcass characteristics. In experiment I alfalfa meal was increased from 4 to 16 or 28% as the individual pigs reached weights of 100, 125 or 150 lb. In experiment II, 18 and 14% protein diets with or without chlortetracycline were fed up to an average lot weight of 125 lb., then the

protein levels were reduced to 15 and 11% and half the lots on each of the two antibiotic treatments were reversed.

In experiment I the increase in alfalfa levels produced significant reductions in rate and efficiency of gain, dressing percent, backfat thickness, total fat percent and bacon thickness. The largest differences were caused by the 28% level of alfalfa. The weight of pig at which alfalfa was increased had little effect on the variables mentioned, although delaying the addition to 150 lb. did significantly improve the grade and increase the length of the carcasses. Significant sex effects in favor of gilts were higher carcass grades and yields of preferred cuts together with decreased bacon and backfat thickness and lower percent of total carcass fat.

In experiment II the use of the high protein diet resulted in the following significant effects: increased feed efficiency, higher carcass grade, greater yield of preferred cuts, thinner back fat and less total carcass fat. Significant response to the antibiotic was limited to the first period of the experiment (up to 125 lb.) in which it increased feed consumption and decreased backfat thickness. In both experiments physical and chemical analyses of the hams reflected the results obtained from the carcass evaluation already described.

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EFFECTS OF STILBESTROL AND A COMBINATION OF PROGESTERONE AND ESTRADIOL ON GROWING-FINISHING SWINE [1, 2]

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BARROWS are fatter than gilts and gilts yield a lower percentage of lean than boars. This sex difference in carcass composition is possibly the result of differences in the type and amount of gonadal hormones produced by males, females and castrates.

The purpose of the present experiment was to investigate the influence of a low level of stilbestrol implant and high and low levels of a progesterone-estradiol combination on growth and carcass composition of barrows.

Experimental Procedure

Forty-eight Poland China barrows were randomly assigned to eight lots of six animals each. A complete-mixed ration (table 1) was fed, and all lots of pigs were maintained in pens with concrete floors.

Two lots of barrows were designated as control (Group I) and six lots, two per treatment, were implanted with the following preparations: (Group II) 6 mg. of stilbestrol; (Group III) 166.7 mg. progesterone and 3.3 mg. estradiol benzoate; (Group IV) 500 mg. progesterone and 10 mg. estradiol benzoate. The implants were made subcutaneously at the base of the ear at the start of the experiment.

The barrows were weighed at weekly intervals and slaughtered upon reaching a body weight of 200 lb. Detailed carcass measurements were made according to procedures outlined in the Proceedings of the Reciprocal Meat Conference (1952).

Results and Discussion

The growth and carcass data of the barrows are summarized in table 2.

Rate and efficiency of gain were not significantly influenced by the stilbestrol or progesterone-estradiol treatments. A trend toward a decrease in the rate of gain apparent in the lots of barrows receiving either stilbestrol or the high level of the progesterone-estradiol combination was not found in the lots administered the low level of the hormone combination. Previous investigations designed to study the rate and efficiency of gain of swine given exogenous estrogens indicate that any improvement following the

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administration of stilbestrol (Woehling *et al.*, 1951; Dinusson *et al.*, 1951; Beeson *et al.*, 1955; Heitman and Clegg, 1957; Tribble *et al.*, 1958; Thrasher *et al.*, 1959) or estradiol benzoate (Sleeth *et al.*, 1953 is small and inconsistent.

The most pronounced difference ($P<.01$) between the control and implanted barrows was the live animal probe of backfat thickness adjusted to a constant body weight of 200 lb. The average backfat probe of barrows administered the high level of the progesterone-estradiol combination was 0.18 inch less than the controls ($P<.01$) and 0.12 inch less than the stilbestrol-treated barrows ($P<.05$). The average backfat probe of the

TABLE 1. PERCENTAGE COMPOSITION OF DIET

Ingredients	From 100 to 125 pounds	From 125 to 200 pounds
Ground corn	78.75	88.50
Soybean oil meal	15.00	7.50
Meat and bone scraps	5.00	2.50
Salt [a]	0.40	0.40
Bone meal	0.20	0.40
Limestone	0.30	0.50
Vitamin A and D supplement	0.10	0.10
B-vitamin supplement [b]	0.10	0.10
B_{12} supplement [c]	0.10	.....
Antibiotic supplement [d]	0.15	.....

[a] Zinc added at rate to supply 50 p.p.m. in complete ration.
[b] Contained 2 gm. riboflavin, 4 gm. pantothenic acid, 9 gm. nicotinic acid and 10 gm. choline per pound.
[c] Contained 10 mg. vitamin B_{12} per pound.
[d] Contained 3.6 mg. chlortetracycline per pound.

barrows implanted with the low level of progesterone and estradiol was significantly different from the controls ($P<.05$) but not from the lots implanted with stilbestrol or a higher level of progesterone and estradiol.

There were no statistically significant differences in carcass measurements between the control and stilbestrol-treated barrows. Small but consistent differences in backfat, loin eye area, dressing per cent and percentage of fat trim suggest that stilbestrol may have increased slightly the proportion of lean in the carcass. However, in contrast to this trend, the average percentage of the four lean cuts for the two groups was very similar. Woehling *et al.* (1951), Pearson *et al.* (1952), Tribble *et al.* (1958) and Thrasher *et al.* (1959) have also observed that the administration of stilbestrol to swine failed to induce a significant increase in carcass leanness. Heitman and Clegg (1957) reported that the implantation of 30 mg. of stilbestrol in feeder pigs weighing 58 to 73 lb. decreased backfat thickness and increased the percentage of lean cuts. Pigs treated at a heavier weight of 108 to 131 lb. were intermediate between the controls and light weight pigs in leanness.

The degree of leanness of the carcasses from barrows on the low level progesterone-estradiol implant (Group III) were intermediate between the controls and the high level (Group IV). Differences between the controls and Group III barrows in various carcass traits were not statistically significant. These findings are in general agreement with those observed by Heitman and Clegg (1957) when the level of the hormone combination implanted was 250 mg. progesterone and 10 mg. estradiol benzoate.

Carcasses from the Group IV barrows were perhaps more like the control carcasses than is indicated by the live probe measurements. Although

TABLE 2. INFLUENCE OF EXOGENOUS HORMONES ON GROWTH, FEED UTILIZATION, BACKFAT PROBE AND CERTAIN CARCASS CHARACTERISTICS

			Progesterone—Estradiol	
Treatment level	Control	Stilbestrol, 6 mg.	166.7 mg. Prog., 3.3 mg. Estradiol	500 mg. Prog., 10 mg. Estradiol
Number of animals	12	12	12	12
Av. initial weight, lb.	101.3	100.8	101.5	100.7
Av. total gain, lb.	101.2	102.5	103.0	102.9
Av. daily gain, lb.	1.85	1.77	1.85	1.74
Feed per lb. gain, lb.	4.23	4.03	4.13	4.03
Backfat probe, in.	1.54	1.48	1.40*	1.36**
Absorption of implants, %	.....	100.0	16.8	21.0
Carcass weight, lb.	155.3	154.5	155.1	153.3
Carcass length, cm.	70.5	71.3	71.4	72.0
Dressing percentage, %	77.6	76.3	76.3	75.9*
Backfat thickness, in.	1.67	1.55	1.60	1.55
Loin area, 10th rib, sq. in.	4.09	4.14	4.04	4.22
Four lean cuts, %	46.5	46.9	46.7	48.2
Trimmed ham, %	19.0	19.4	19.3	19.7
Trimmed loin, %	14.0	14.1	13.9	14.6
Trimmed shoulder, %	13.4	13.4	13.5	13.9
Trimmed belly, %	14.7	14.7	15.3	14.5
Total fat trim, %	22.9	21.9	22.0	21.3

* Difference between control and implanted groups of barrows significant at the 5 percent level.
** Difference between control and implanted groups of barrows significant at the 1 percent level.

a treatment effect on the yield of lean appeared to exist for some traits, little difference was found between the two groups in other characteristics indicative of leanness. The average percentage of four lean cuts was higher for Group IV than for the controls. This difference of 1.7% was significant at the 7% level. Although the average differences between Group IV and the controls in loin eye area, percentage of total fat trim and backfat thickness were not statistically significant, they did indicate rather consistently that the progesterone-estrogen treatment decreased the proportion of carcass fat and increased the yield of lean.

The percentage of the progesterone-estradiol pellets absorbed during the experimental period was rather low. At the time they were removed,

which was 1 to 2 days before slaughter, nearly all of the pellets had become encapsulated. The average amounts of the implants absorbed daily by the barrows in Groups III and IV were 0.5 and 1.9 mg., respectively. Apparently, the 6-mg. stilbestrol pellets were absorbed completely as no residue could be located in the ear at slaughter.

The hormone treatments produced no apparent detrimental side effects. The accessory sex glands of the treated animals were similar in size to those of the controls and sexual behavior was unaffected.

Summary

Forty-eight Poland China barrows were used in an experiment designed to study the influence of subcutaneous stilbestrol and progesterone-estradiol (high and low level) implants on average daily gain and carcass composition.

The hormone implants had no significant effect on gain; although stilbestrol and the high level progesterone-estradiol combination (500 mg. —10 mg.) tended to reduce growth rate.

The progesterone-estradiol implants decreased average backfat probe significantly.

Carcasses of the control and treated barrows were similar; however, those from barrows implanted with the high level of progesterone and estradiol showed a trend toward increased leanness.

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SOYBEAN OIL MEAL AS A PROTEIN SOURCE FOR SUCCESSIVE GENERATIONS OF SWINE

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THE use of soybean oil meal in swine rations has been under investigation for more than 40 years. Studies have related primarily to the influence of different processing methods on feeding quality and to the specific nutrient requirements of growing-finishing swine when soybean oil meal was used as a portion or all of the supplemental protein.

Robison (1951, 1953, 1956) reported that the performance of pigs fed properly supplemented corn-soybean oil rations was equal to that of pigs fed rations containing a combination of plant and animal proteins. The effect of continued feeding of all-plant rations to breeding stock and their subsequent offspring has not been reported. Fowler and Robertson (1954) found that animal protein in the ration for gilts resulted in an earlier age at puberty and increased ovulation rate. A gradual depletion of factors essential for reproduction in female rats maintained on an all-plant diet was suggested by Emerson *et al.* (1950) and Shultze (1953).

In the generation study here reported, soybean oil meal alone or in combination with meat and bone scraps was used to supply supplemental protein in dry-lot rations. Groups of swine were continuously fed one of the two types of rations through the farrow of 4th generation pigs.

Experimental Procedure

The study began in the spring of 1955 and ended in the spring of 1958. Two groups of 10 Duroc gilt pigs served as foundation stock. These first generation females were permitted to farrow three times. Subsequent generations of animals used in the study were derived from this original stock.

The experimental design, showing the number of females farrowed and those slaughtered to obtain prenatal information on each of the two ration treatments, is shown in figure 1. Performance data during the growing-finishing period were obtained on all gilts saved as breeding stock and on two groups of second generation pigs from the second farrow of the original females.

Pigs, gilts and sows, designated as Lot 1, were fed complete rations containing plant materials with soybean oil meal used as the only source of supplemental protein. Animals in Lot 2 were fed complete rations in which half of the supplemental protein was supplied as soybean oil meal

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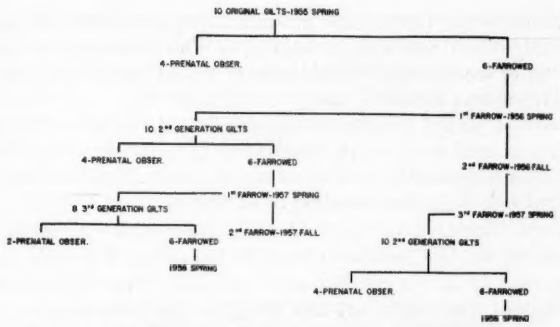

Figure 1. A diagram of experimental design showing the number of bred gilts slaughtered during gestation and the number of gilts or sows farrowed on each of the two ration treatments.

and half as meat and bone scraps. Composition of the rations is shown in table 1. The calculated protein and mineral content as well as the vitamin and antibiotic supplementation of the all-plant and plant and animal protein rations were equalized. Samples of each ration were analyzed for protein content. In no case was the amount of protein by analysis below

TABLE 1. PERCENTAGE COMPOSITION OF RATIONS

Ingredients	Lot 1. All-plant				Lot 2. Plant and animal			
	Wean. to 120 lb.	120 lb. to mkt. wt.	Breed.-gest.	Lactation	Wean. to 120 lb.	120 lb. to mkt. wt.	Breed.-gest.	Lactation
Ground corn	75.1	80.5	52.6	56.6	79.6	83.8	56.5	60.8
Ground oats	....	....	15.0	....	....	....	15.0	....
Wheat midds.	....	....	....	15.0	....	....	....	15.0
Meat and bone scraps, 55%	....	....	....	....	6.1	4.0	5.3	5.6
Soybean oil meal, 44%	16.0	10.6	13.9	14.9	7.6	5.0	6.6	7.0
Alf. meal, 17%	5.0	5.0	15.0	10.0	5.0	5.0	15.0	10.0
Minerals A [a]	3.3	3.3	2.9	2.9	....	....	....	....
Minerals B [b]	....	....	....	....	1.1	1.6	1.0	1.0
Vit. antib. premix 1 [c]	0.6	0.6	....	....	0.6	0.6	....	....
Vit. antib. premix 2 [d]	....	....	0.6	0.6	....	....	0.6	0.6
Calculated composition:								
Crude protein	14.3	12.3	15.0	15.5	14.3	12.3	15.0	15.5
Calcium	0.90	0.88	0.96	0.88	0.89	0.83	0.96	0.90
Phosphorus	0.55	0.52	0.53	0.58	0.58	0.52	0.56	0.63

[a] Trace mineralized salt, 19.2; limestone, 25.6; special steamed bone meal, 51.2; ferrous sulfate, 3.9; and zinc sulfate, 0.1 percent.

[b] Trace mineralized salt, 19.2; limestone, 38.4; special steamed bone meal, 38.4; ferrous sulfate, 3.8; and zinc sulfate, 0.2 percent.

[c] American Cyanamid B-vitamin supplement. "Fortafeed 2–49C", 1.5; aureomycin supplement. "Aurofac 2A", 1.0 and vitamin B-12 supplement. "Profactor 10", 0.5 lb. plus 3.0 lb. soybean oil meal.

[d] American Cyanamid B-vitamin supplement. "Fortafeed 2–49C", 1.5 and vitamin B-12 supplement. "Profactor 10", 0.5 lb. plus 4.0 lb. soybean oil meal.

the calculated level. During the growing-finishing period the pigs were self-fed, and weight and feed consumption were measured at two-week intervals. After the animals reached market weight the rations were hand-fed in equal amounts to both groups.

Gilts were at least 7 months of age when bred. As shown in figure 1, usually four in each group were slaughtered 55 to 57 days after breeding. Data obtained included the number of corpora lutea present on the ovaries and the number, condition and weight of all fetuses.

All animals remained on concrete floors throughout the study. Duroc boars from the Station herd were used for breeding. A central farrowing house was used for farrowing. The sows and litters were moved to outdoor concrete-floored pens within the first 14 days after farrowing.

TABLE 2. PRENATAL OBSERVATIONS FROM THE SLAUGHTER AND EXAMINATION OF BRED GILTS IN EACH GENERATION (MID-GESTATION)[a]

Lot and ration	Lot 1. All-plant				Lot 2. Plant and animal			
Season	1956 spring	1957 spring	1958 spring	1958 spring	1956 spring	1957 spring	1958 spring	1958 spring
Generation	First	Second[b]	Second[c]	Third[d]	First	Second[b]	Second[c]	Third[d]
Number of gilts	4	4	4	1[e]	4	4	4	2
Corpora lutea, av.	16.2	14.2	14.5	13.0	14.0	13.5	14.7	12.5
Live fetuses, av.	11.2	11.0	11.8	7.0	10.7	10.2	10.8	11.0
Dead fetuses, av.	1.7	0.2	0.2	0.0	0.5	0.5	0.2	0.0
Live fetuses, as % of corpora lutea	69.	77.	81.	54.	76.	76.	73.	88.
Av. wt. of live fetuses, gm.	68.	81.	80.	75.	83.	78.	77.	79.

[a] Fifty-five to fifty-seven days after breeding.
[b] From first farrow of original females (1956 spring).
[c] From third farrow of original females (1957 spring).
[d] From first farrow of second generation females (1957 spring).
[e] Remaining gilt died of a kidney infection early in gestation.

Results and Discussion

Breeding Performance and Prenatal Observations. The type of ration fed, whether all-plant or of plant and animal origin, had no apparent effect on the estrual behavior of the gilts or sows. Conception rate was considered satisfactory for all groups of females in each generation irrespective of ration treatment.

Prenatal observations from the slaughter of bred gilts is summarized in table 2. At this mid-point in the gestation period, first and second generation animals fed all-plant rations possessed a greater average number of live fetuses. In the spring of 1956 and 1957 they also possessed a greater average number of corpora lutea. Assuming fertilization rate to have been equal, an estimate of survival rate is indicated by comparing the number of fetuses to the number of corpora lutea present. This percentage was greater for the Lot 1 females in the spring of 1957 and 1958 only. Fowler

and Robertson (1954) reported no difference in the number of live embryos at 25 days as influenced by the feeding of all-plant or plant and animal protein rations. Although not a significant difference, these authors reported increased ovulation rate was associated with the feeding of animal protein. Average fetal weight was not consistently greater for fetuses from sows in either lot or for those in any generation.

By a comparison of observations made from the slaughter of the bred gilts at mid-gestation and farrowing performance of those remaining, it was possible to obtain indirect information regarding prenatal performance during the remainder of the gestation period. Although average fetal weight

TABLE 3. FARROWING AND LACTATION PERFORMANCE OF FIRST GENERATION SOWS (THREE FARROWINGS)

Lot and ration	Lot 1. All-plant			Lot 2. Plant and animal		
Season	1956 spring	1956 fall	1957 spring	1956 spring	1956 fall	1957 spring
Farrow	First	Second	Third	First	Second	Third
Number of sows	6	6	6	6	6	5[a]
Gestation days, av.	115.3	113.7	115.3	114.0	114.2	114.0
Live pigs farrowed, av.	10.2	9.5	8.7	10.7	10.2	9.6
Pigs stillborn, av.	1.2	2.0	2.0	0.2	1.0	1.4
Av. birth wt. of live pigs, lb.	2.25	2.67	2.47	2.46	2.59	2.85
Vigor classification at birth, %						
Vigorous	54.1	52.6	53.8	64.1	52.5	58.3
Lacking in vigor	37.7	36.9	42.3	26.5	32.8	35.4
Weak	8.2	10.5	3.9	9.4	14.7	6.3
Av. litter size, 56 days	7.8	7.3	7.3	9.7	6.7	7.2
Av. wt. of pigs, 56 days, lb.	33.3	31.2	39.7	35.2	36.6[b]	36.5

[a] Remaining sow observed in heat 108 days after breeding. Slaughter and examination revealed no evidence of earlier pregnancy or reproductive abnormality.

[b] For five litters. One late litter weaned at 21 days.

did not appear to differ with ration treatment, the birth weight of the Lot 2 pigs was significantly greater ($P<0.01$) than the weight of pigs farrowed by Lot 1 females (tables 3, 4 and 5). Thus, the feeding of rations containing plant and animal protein appears to have resulted in increased prenatal growth during the second half of the gestation period.

The relatively poor performance of the single third generation gilt slaughtered for examination in Lot 1 is not consistent with the very satisfactory farrowing record of the remainder of the gilts in this lot (table 5).

First Generation Gilt and Sow Performance. A summary of the farrowing and lactation performance of the first generation females is shown in table 3.

At the time of the first and third farrowings, gestation length for Lot 1 sows averaged 1.3 days longer than for the sows in Lot 2. In each season the average number of live pigs farrowed was greater for Lot 2 sows which

TABLE 4. FARROWING AND LACTATION PERFORMANCE OF SECOND GENERATION SOWS

Lot and ration	Lot 1. All-plant			Lot 2. Plant and animal		
Group	Group 1[a]		Group 2[b]	Group 1[a]		Group 2[b]
Season	1957 spring	1957 fall	1958 spring	1957 spring	1957 fall	1958 spring
Farrow	First	Second	Third	First	Second	Third
Number of sows	6	4	6	6	5[d]	6
Gestation days, av.	117.2[c]	114.5	114.7	115.3	114.4	114.7
Live pigs farrowed, av.	4.5	11.0	11.7	7.8	9.6	9.5
Pigs stillborn, av.	4.5	0.5	0.2	0.8	1.0	0.0
Av. birth wt. of live pigs, lb.	2.33	2.65	2.74	2.51	2.82	2.91
Vigor classification at birth, %						
Vigorous	27.	52.	54.	62.	62.	70.
Lacking in vigor	56.	39.	39.	36.	23.	19.
Weak	17.	9.	7.	2.	15.	11.
Av. litter size, 21 days	4.0	9.7	10.5	6.7	8.8	8.5
Av. wt. of pigs, 21 days, lb.	9.6	11.8	11.2	12.3	11.9	12.4

[a] From first farrow of original females (1956 spring).
[b] From third farrow of original females (1957 spring).
[c] Does not include two gilts which failed to farrow and were slaughtered on the 119th and 120th day of gestation. Each possessed a litter of ten dead and regressing young.
[d] One sow failed to farrow. Autopsy revealed an edematous condition of the fallopian tubes.

were fed rations containing both plant and animal protein. The number of live pigs at 56 days was greater only for the litters from their first farrow.

In two of the three seasons average weight at birth and 56-day weight was greater for pigs farrowed by Lot 2 females. Vigor of the pigs at birth in these three farrowings was not influenced in any consistent manner by the type of ration fed to the dam.

TABLE 5. FARROWING AND LACTATION PERFORMANCE OF THIRD GENERATION GILTS (1958 SPRING)[a]

Lot and ration	Lot 1 All-plant	Lot 2 Plant and animal
Number of gilts	6	6
Gestation days, average	115.3	114.5
Live pigs farrowed, average	10.2	11.2
Pigs stillborn, average	1.0	1.0
Av. birth wt. of live pigs, lb.	2.60	2.84
Vigor classification at birth,%		
Vigorous	56.	67.
Lacking in vigor	36.	27.
Weak	8.	6.
Average litter size, 21 days	8.2	10.5
Av. wt. of pigs, 21 days, lb.	10.5	10.9

[a] Gilts from first farrow of second generation gilts (1957 spring).

Neither leg stiffness nor other leg ailments of a serious nature was encountered in either group of sows during the two-year period of confinement on concrete. By the end of this period some difference in color of the sows was noted; those which had been fed the all-plant rations being lighter red than those which were fed the mixed protein rations.

Second Generation Gilt and Sow Performance. The farrowing and lactation performance of second generation gilts and sows is shown in table 4. A prolonged gestation period and high prenatal death loss was observed in the first group of gilts farrowed. This was most evident in Lot 1 where two which failed to farrow were slaughtered 119 and 120 days after breeding. Both possessed a litter of 10 dead and regressing young. A third gilt farrowed a litter of 10 stillborn pigs on the 119th day of gestation. Judged by their size and stage of development, death of all pigs in these litters appeared to have occurred near the 80th day of gestation. Seven of the eight remaining stillborn pigs farrowed by gilts in this lot had reached a similar state of development prior to death. In all, a total of 18 live and 38 stillborn pigs were farrowed by the six gilts in Lot 1, including those recovered after slaughter.

Contrasted to this high incidence of prenatal loss, gilts in Lot 2 farrowed 47 live and 5 stillborn pigs. The latter were present in two of the six litters. In all of the three farrowings, second generation pigs from Lot 2 females possessed greater average vigor at birth.

It is important to note that when the first group of sows were farrowed a second time (1957 fall) their performance appeared normal in all respects. In this instance the four remaining Lot 1 sows farrowed an average of more live and fewer stillborn pigs than those which were fed the mixed protein rations.

No evidence of prolonged gestation or high prenatal death loss was observed when the second group of gilts was farrowed in the spring of 1958. In this instance there was again a greater average number of live pigs farrowed and pigs alive at 21 days in litters farrowed by the gilts which had received all-plant rations.

Third Generation Gilt Performance. Performance of third generation gilts is shown in table 5. The average length of gestation was somewhat greater for those in Lot 1. However, in this instance there was no evidence of a high prenatal death loss or failure to farrow. An average of one more live pig was farrowed and 2.3 more were alive at 21 days in the litters farrowed by Lot 2 gilts.

In litters farrowed by all groups of second and third generation females a greater percentage of the pigs farrowed by gilts or sows which had received the mixed protein rations were classified as vigorous at birth and the difference in birth weight was also highly significant ($P<0.01$). This greater weight and vigor of Lot 2 pigs at birth was not always reflected in increased postnatal livability or weaning weight. (table 3, 4 and 5). In view of the lack of any consistent difference in the weight or vigor of pigs

at weaning time, or death loss during the suckling period, it is assumed that lactation performance on the two types of rations was similar.

Growing-finishing Performance. Performance of original gilts and pigs from their first three farrowings is shown in table 6. Differences in the rate of gain of pigs on the two ration treatments within and between seasons were small. In two seasons, pigs in Lot 1 fed all-plant rations gained somewhat faster while in two other seasons pigs in Lot 2 made faster gains. Similarly, only small differences in the amount of feed required per 100-lb. gain were obtained. The ability of pigs fed all-plant rations to perform as well as those fed rations containing plant and animal protein is in agreement with results reported by Robison (1953, 1956).

TABLE 6. GROWING-FINISHING PERFORMANCE OF ORIGINAL GILTS AND PIGS FROM THEIR FIRST THREE FARROWINGS

Gilts and pigs	Original gilts		Second generation pigs					
Season	1955 spring		1st farrow 1956 spring		2nd farrow 1956 fall		3rd farrow 1957 spring	
Ration of dam and pigs	All-plant	Plant and animal	All-plant	Plant and animal	All-plant	Plant and animal	All-plant	Plant and animal
Number of pigs	10	10	10	10	8	8	10	10
Av. initial wt., lb.	50.4	50.1	38.6	40.1	34.8	39.9	57.7	52.2
Av. final wt., lb.	208.7	201.8	209.6	210.9	208.1	207.4	217.3	215.6
Av. daily gain, lb.	1.62	1.55	1.53	1.64	1.77	1.60	1.66	1.70
Av. daily feed consumed, lb.	5.59	5.37	5.37	5.78	6.27	5.74	5.67	5.77
Feed per 100 lb. gain, lb.	346.	347.	352.	349.	355.	360.	341.	339.

Summary

Groups of swine, confined to dry lot, were fed rations containing all-plant or plant and animal products through the farrow of fourth generation pigs. Supplemental protein was supplied in complete rations as either soybean oil meal or a combination of soybean oil meal and meat and bone scraps. A total of 755 pigs were farrowed during the three-year period.

Satisfactory performance was maintained on both ration treatments. Breeding performance, fetal weight at mid-gestation, lactation performance (including livability and growth of pigs to weaning) and growing-finishing performance did not appear to be effected by the type of ration fed.

The continuous feeding of rations containing both plant and animal products resulted in a highly significant increase in birth weight ($P<0.01$) and greater average vigor at birth in pigs farrowed by second and third generation females.

A high incidence of late prenatal death loss was observed in one group

of second generation gilts fed all-plant rations. Second farrowing performance of the same females appeared normal in all respects.

From observations during the three-year period there apparently was no decline in performance either from ration treatment or as a result of continual confinement on concrete.

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UTILIZATION OF RATIONS CONTAINING DIFFERENT PROPORTIONS OF ROUGHAGE AND CONCENTRATE AS MEASURED BY TDN AND DE [1]

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THE use of digestible energy (DE) determined by a bomb calorimeter is rapidly supplanting the less accurate and more tedious total digestible nutrient (TDN) method of measuring energy. Lofgreen (1951), Crampton (1957), and Swift (1957) pointed out that DE and TDN are very highly correlated, being different methods of measuring the same biological function. Much work has been done by these men and others to convert existing TDN data into terms of DE. Swift (1957) stated that to convert TDN to DE, one has only to multiply the weight of TDN in pounds by the factor 2,000 to obtain the equivalent in Calories. Crampton *et al.* (1957) concluded that the caloric value of TDN for swine was not constant but depended on the ether extract content of the ration. Barth *et al.* (1959) found that the conversion factors between TDN and DE were not affected by the ether extract in high roughage rations, but were affected by percentage of digestible protein.

Work at this station by Cox (1948) established that there is a desirable physical balance in rations for fattening lambs. It was concluded that a roughage to concentrate ratio of 55:45 was best for optimum gains and feed efficiency. Later work by Neale (1955) and Menzies *et al.* (1958) showed that equally good results were obtained with a wider ratio when the entire ration was ground and made into pellets.

The purposes of this paper are to report the correlation between DE and TDN and the proper ratio of roughage to concentrate in the ration for fattening lambs.

Experimental Procedure

Nine lambs averaging 90 lb. each were put in metabolism crates designed for separate collection of feces and urine. Each collection period consisted of 7 days after the lambs were adjusted to the rations and crates. The lambs were fed three different preparations of alfalfa hay and sorghum grain. Three lambs were fed the ration non-pelleted; three, as pellets; and

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three, as pellets plus 100 gm. of chopped alfalfa hay per lamb per day. They were hand-fed twice daily and provided with fresh water *ad libitum*.

Four collections of 7 days each were made with a 12-day period between collections for the lambs to adjust to the new rations. The rations and ratios of roughage to concentrate were as follows: 1st collection, 80% alfalfa hay and 20% sorghum grain; 2nd collection, 70% alfalfa hay and

TABLE 1. AVERAGE PERCENTAGE OF DIGESTIBLE ENERGY AND TOTAL DIGESTIBLE NUTRIENTS BASED ON RATION PREPARATION

Ration	Percent DE	Percent TDN	Calories per kilogram TDN	Calories per pound TDN
Non-pelleted				
80:20	58.93	54.82	4373.6	1985.3
70:30	68.61	62.21	4478.6	2032.9
60:40	64.88	60.10	4371.7	1984.5
50:50	66.74	61.11	4420.4	2006.6
Average	64.79	59.56	4411.1	2002.3
Pelleted				
80:20	61.93	54.80	4438.4	2014.3
70:30	66.50	61.09	4439.9	2015.4
60:40	68.25	63.05	4419.8	2006.3
50:50	69.34	62.00	4393.9	1991.4
Average	66.51	60.24	4423.0	2006.9
Pelleted + hay				
80:20	50.58	47.98	4304.0	1953.7
70:30	62.69	57.15	4423.3	2007.8
60:40	66.55	60.84	4402.6	1998.5
50:50	67.29	60.48	4385.7	1977.5
Average	61.78	56.61	4378.9	1976.9

30% sorghum grain; 3rd collection, 60% alfalfa hay and 40% sorghum grain; and 4th collection, 50% alfalfa hay and 50% sorghum grain.

Representative samples of the chopped alfalfa hay, sorghum grain, and four different types of pellets were weighed, dried and ground in a Wiley mill. These samples were stored in air-tight glass jars for use in DE and TDN determinations. Feces from each lamb were collected every afternoon during the 7 days of each collection period. The feces were weighed and a 5% aliquot was placed in a porcelainized pan and dried in an oven at 90° C. After the seventh collection was dried, the samples were weighed and finely ground. All samples were further dried to constant weight at 100° C. under vacuum and stored in a desiccator for

nutrient and energy determinations. Energy determinations were made with a Parr oxygen bomb calorimeter.

Results and Discussion

The DE was significantly ($P<0.01$) correlated with TDN in this experiment as would be expected since both are measures of the same

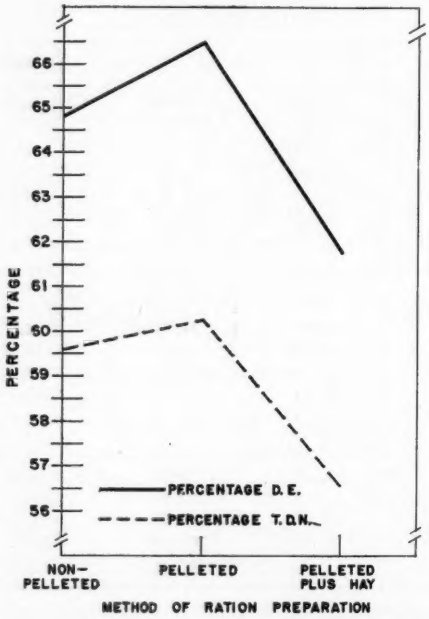

Figure 1. Percentage DE and percentage TDN as affected by ration preparation.

biological function. The correlation coefficients between DE and TDN were 0.986, 0.957, and 0.996 for non-pelleted, pelleted, and pelleted plus hay rations, respectively. The results are shown in table 1. The average Calories per pound of TDN were 2002, 2007, and 1977 for non-pelleted, pelleted, and pelleted plus hay rations, respectively. These figures agree with the figures of 1997 and 2007 Calories per pound of TDN reported by Crampton (1957) and Swift (1957). Figure 1 shows these results in percentages of DE and TDN as affected by ration preparation.

DE and TDN were compared in table 2 according to ratio of roughage to concentrate. The Calories per pound of TDN for the 80:20 ratio was 1986; this figure increased to 2019 for the 70:30 ratio and dropped to 1996, and 1992, respectively, for the 60:40 and 50:50 ratios. The percentages of DE and TDN are shown in graphic form in figure 2.

The correlation coefficients between DE and TDN were also statistically significant ($P<0.01$). They were 0.990, 0.993, 0.991, and 0.933, for rations

TABLE 2. AVERAGE PERCENTAGE OF DIGESTIBLE ENERGY AND TOTAL DIGESTIBLE NUTRIENTS BASED ON RATIO OF ROUGHAGE TO CONCENTRATE

Ration	Percent DE	Percent TDN	Calories per kilogram TDN	Calories per pound TDN
80:20				
Non-pelleted	58.93	54.82	4373.6	1985.3
Pelleted	61.93	54.80	4438.4	2014.3
Pelleted + hay	50.58	47.98	4304.0	1953.7
Average	57.25	52.98	4371.7	1986.4
70:30				
Non-pelleted	68.61	62.21	4478.6	2032.9
Pelleted	66.50	61.09	4439.9	2015.4
Pelleted + hay	62.69	57.15	4423.3	2007.8
Average	65.74	60.37	4447.3	2018.7
60:40				
Non-pelleted	64.88	60.10	4371.7	1984.4
Pelleted	68.25	63.05	4419.8	2006.3
Pelleted + hay	66.55	60.84	4402.6	1998.5
Average	66.69	61.88	4398.0	1996.4
50:50				
Non-pelleted	66.74	61.11	4420.4	2006.6
Pelleted	69.34	62.00	4393.9	1991.4
Pelleted + hay	67.29	60.48	4385.7	1977.5
Average	67.79	61.19	4400.0	1991.8

with ratios of roughage to concentrate of 80:20, 70:30, 60:40, and 50:50, respectively.

Figure 2 shows a sharp increase in both DE and TDN from the 80:20 to 70:30 ratio, and a gradual increase to the 60:40 ratio. The DE continued to rise gradually but the TDN, for some reason undetermined, dropped slightly at the 50:50 ratio of roughage to concentrate. These results verify the work of Cox (1948) that there is an optimum ratio of roughage to concentrate for lamb fattening rations. Further work is needed to determine the influence of smaller and larger amounts of concentrates.

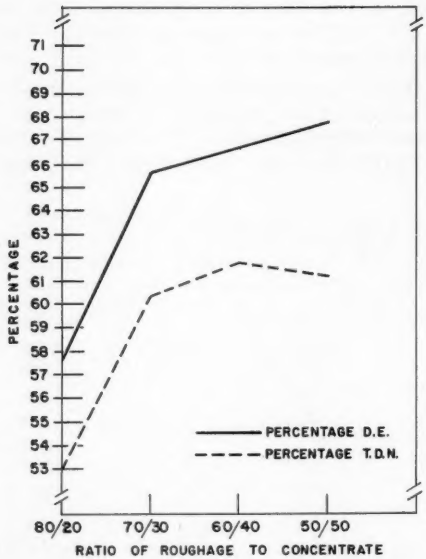

Figure 2. Percentage of DE and percentage of TDN as affected by the ratio of roughage to concentrate.

Although the DE and TDN values were not statistically higher for pelleted rations over non-pelleted rations, they were higher at three of the four ratios of roughage to concentrate.

Summary

DE and TDN determinations were made with lambs on non-pelleted, pelleted, and pelleted plus hay rations with roughage to concentrate ratios of 80:20, 70:30, 60:40, and 50:50, respectively. Correlation coefficients for percentage DE and TDN were highly significant with all rations. This justifies the suggestion of other research workers that DE replace TDN values, which require much more work to obtain. DE and TDN values were higher, but not significantly, for pelleted than non-pelleted or pelleted plus hay rations.

The results indicated 30% as the minimum and 50% as the maximum concentrate in lamb fattening rations for best utilization. This was influenced by method of preparation. This work showed that, for practical application, 1 lb. of TDN was equivalent to 2,000 Calories.

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THE NUMBER OF DAUGHTER-DAM PAIRS NEEDED FOR ESTIMATING HERITABILITY

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THE number of observations required to obtain reliable estimates of heritability has been discussed recently for the method which utilizes the intra-class correlation coefficient. Wearden (1959) has made use of the power function to determine the number of progeny per sire needed to estimate heritability. Tallis (1959), utilizing the formula for the variance of the intra-class correlation coefficient as given by Fisher (1952), has discussed the minimum number of offspring necessary for estimating heritability with a given accuracy.

Another method of estimating heritability is from the regression of daughter records on dam records. These estimates are subject to sampling variances and many daughter-dam pairs must be used in order to obtain accurate estimates of heritability. It is, therefore, useful to know the number of pairs needed to estimate heritability with a pre-set standard error of the estimate.

In the one-way classification analysis (where classes are often herds or sires) the estimated variance of the regression coefficient (b) is

$$V(b)=\frac{\Sigma y^2-\frac{(\Sigma xy)^2}{\Sigma x^2}}{(N-S-1)\Sigma x^2}, \qquad (1)$$

where Σy^2=the within class sum of squares of the dependent variable (daughter records),

Σx^2=the within class sum of squares of the independent variable (dam records),

Σxy=the within class sum of crossproducts of daughter and dam records,

N=total number of daughter-dam pairs, and

S=total number of classes.

Dividing both the numerator and denominator by Σx^2 we have:

$$V(b)=\frac{\frac{\Sigma y^2}{\Sigma x^2}-\frac{(\Sigma xy)^2}{(\Sigma x^2)^2}}{N-S-1}.$$

Since heritability, G, is estimated as $2b=\frac{2(\Sigma xy)}{(\Sigma x^2)}$ when assuming no

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relationship between daughters within classes, V(2b) can be expressed as

$$4V(b)=V(G)=4\left(\frac{\frac{\Sigma y^2}{\Sigma x^2}-\frac{G^2}{4}}{N-S-1}\right).$$

Dividing both numerator and denominator of $\frac{\Sigma y^2}{\Sigma x^2}$ by N—S, we have

$$V(G)=4\left(\frac{\frac{\hat{\sigma}_y^2}{\hat{\sigma}_x^2}-\frac{G^2}{4}}{N-S-1}\right), \tag{2}$$

where $\hat{\sigma}_y^2$=the estimated error variance of daughter records, and
$\hat{\sigma}_x^2$=the estimated error variance of dam records.

For convenience let us set $X=\frac{\hat{\sigma}_y^2}{\hat{\sigma}_x^2}$. Now if we let $R=\frac{N}{S}$=average number of pairs per class and solve equation (2) for N we obtain

$$N=\frac{(R)}{(R-1)}\,\frac{[4X-G^2+V(G)]}{V(G)}. \tag{3}$$

When heritability is estimated, the ratio of variances, X, usually approximates to 1; R is known or estimated; and V(G) is fixed in order to obtain a certain confidence interval. Then, for an anticipated value of G, the number of daughter-dam pairs required in order to estimate G with a predetermined standard error may be estimated. It can be seen that N increases with an increase in X, but decreases as R, G, and V(G) increase.

Assuming X=1, a quick approximation to N can be given as $N=\frac{(R)}{(R-1)}\,\frac{4}{V(G)}$. Setting G=0 will tend to overestimate the number required. For $R\geqslant 12$ and X=1, N can be approximated by $\frac{4}{V(G)}$ for anticipated values of $G\leqslant .50$.

Figure 1 can be used to estimate the number of daughter-dam pairs needed if it can be assumed that the ratio of daughter to dam variances is 1. The values plotted are for a desired standard error of the heritability estimate of 0.04. Values for multiples (p) of 0.04 can be obtained by multiplying the value taken from the graph by $\frac{1}{p^2}$. Since $G\pm 2[V(G)]^{1/2}$ is the approximate 95 percent confidence interval of estimated G, the number of pairs required for obtaining estimates of $G\pm 2[V(G)]^{1/2}$ can also be obtained from figure 1. It should be observed that doubling the confidence interval desired reduces the number of pairs required by a factor of 4.

As an example, suppose that the ratio of variances is 1, the average number of pairs per herd is 4, the heritability of the trait is thought to be 0.4, and that a confidence interval of $\pm 2(.12)$ is desired. Now $0.12=3(.04)$ and therefore p=3. From the graph we find for R=4 and heritability

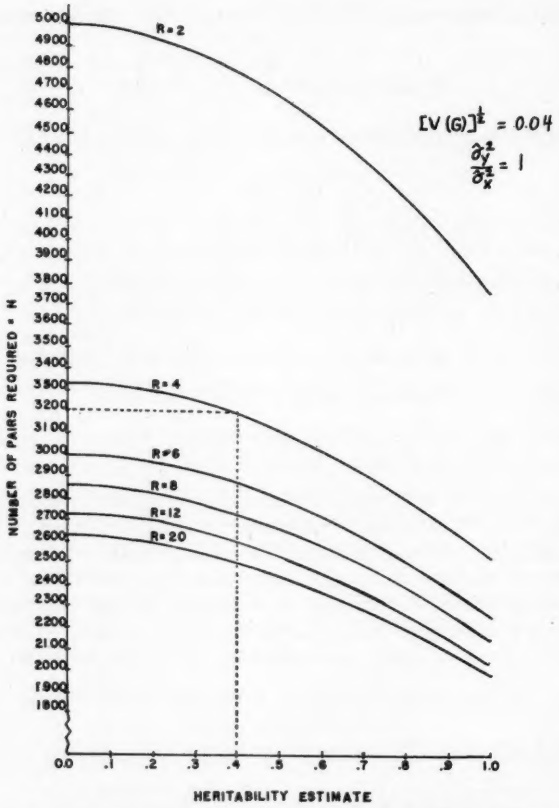

Figure 1. The required number of daughter-dam pairs, N, needed to estimate heritability for various values of the expected heritability estimate, G, and for several values of average number of pairs per class, R, when the standard error of the estimate is set at .04 and the ratio of daughter to dam variances=1.

$=0.4$ that 3200 pairs are required when $[V(G)]^{\frac{1}{2}}=0.04$. Multiplying 3200 by $\frac{1}{3^2}$ gives 356 which is the number of pairs needed. This result may also be obtained by application of equation (3).

This procedure may be easily extended to a many way classification since only within subclass variance and covariance components are used. In this analysis the sums of squares and crossproducts in equation (1) are within subclass sums of squares and crossproducts.

The number of pairs of records needed to estimate repeatability by regression of second records on first records may be determined similarly. Let the estimate of repeatability = b. Then the estimate of V(b) is that given in equation (1). Since $b=\frac{\Sigma xy}{\Sigma x^2}$ this variance can be written as

$$V(b)=\frac{\frac{\hat{\sigma}_y^2}{\sigma_x^2}-b^2}{N-S-1},$$

where $\hat{\sigma}_y^2$ = the estimated error variance of second records,
$\hat{\sigma}_x^2$ = the estimated error variance of first records, and
S = the number of subclasses.

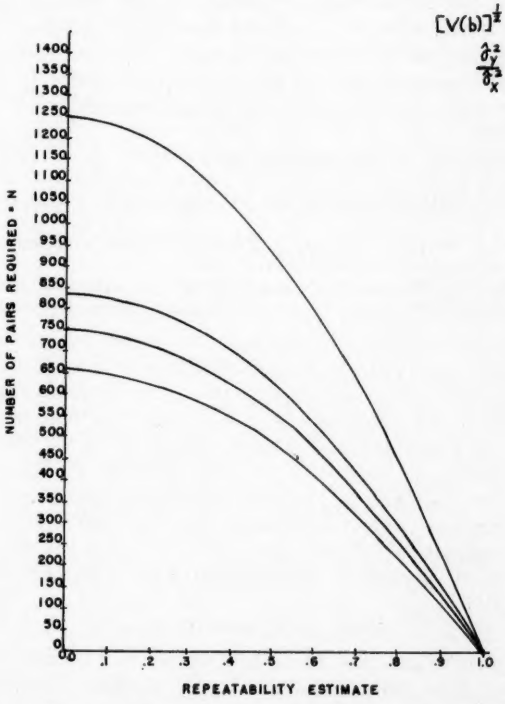

Figure 2. The required number of pairs of records, N, needed to estimate repeatability for various values of the expected repeatability estimate, b, and for several values of average number of pairs per class when the standard error of the estimate is set at .04 and the ratio of variances=1.

Substituting $X=\frac{\hat{\sigma}_y^2}{\hat{\sigma}_x^2}$ and $R=\frac{N}{S}$ and solving for N we obtain

$$N=\frac{(R)}{(R-1)}\ \frac{[X-b^2+V(b)]}{V(b)}.$$

The number of pairs of records needed when $X=1$ for various values of R, b, and V(b) may be obtained from figure 2.

Summary

A formula for estimating the number of daughter-dam pairs needed when estimating heritability by daughter on dam regression in the one-way classification analysis for fixed values of the average number of pairs per class, of the ratio of daughter to dam variance, of the anticipated heritability estimate, and of the desired variance of the estimate has been presented. The effect on N of changes in these four variables has been illustrated. This procedure was extended to multiple classification analysis and was also used to determine the number of pairs needed to estimate repeatability by regression of second records on first records.

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ENVIRONMENTAL COMPARISONS OF SWINE PERFORMANCE AS AFFECTED BY SHADED AND UNSHADED WALLOWS [1]

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University of California

THE effectiveness of a water wallow in alleviating heat stress and increasing swine production in hot weather is well recognized by the producer and has been proved by experiment (Bray and Singletary, 1948; Andrews *et al.*, 1956; Heitman *et al.*, 1959).

Heitman *et al.* (1959) showed no difference between shaded and unshaded wallows when the average mean temperature was 75° F. and the average maximum temperature was 94° F. In many hog producing areas, however, mean and maximum air temperatures are considerably higher than this. In the Imperial Valley of California, for example, the mean daily air temperature during the summer is near 90° F., and the average maximum temperature may be between 105 and 110° F. During the hotter part of the day the water in wallows exposed to the sun may reach or exceed the normal body temperature of the hog. Shaded and unshaded wallows for swine were compared in this type of environment.

Experimental

Similar trials were conducted during the summers of 1957, 1958, and 1959. Two experimental pens, 25′ x 28′, oriented with length north to south, were paved with concrete and enclosed by wire fence. Each pen was equipped with a self feeder, an automatic waterer, and a shelter, 8′ x 14′ x 8′, centrally oriented east to west, open on the north and south and placed 6′ from the southern fence. A concrete wallow 8.5′ x 10′ was located in the northeast corner of each pen. One wallow was shaded by a hay-covered structure 11.5′ x 15′ and 6.5′ high.

The experimental feeder pigs were purebred Durocs in 1958, and of mixed breeds in the other two years. Both barrows and gilts were represented, each sex being assigned at random to the treatments. The pigs were self-fed rations similar to those used by Heitman *et al.* (1959).

Results and Discussion

The environment as recorded at a weather station near the hog pen is summarized in table 1. Animal response to the modified environment is shown in table 2.

[1] The 1957 test reported here was initiated under the direction of N. R. Ittner (deceased). The authors wish to acknowledge the inspiration he provided. The authors also acknowledge the assistance of Herdsmen, Phil Trask and Delbert Gaskin.

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TABLE 1. SUMMARY OF THE ENVIRONMENT DURING THE EXPERIMENTAL PERIODS[a]

Year	Av. air temperature, °F.			Av. relative humidity, %			Av. air velocity, mph
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	
1957	107.7	74.9	91.1	59	19	37	3.0
1958	109.1	73.3	91.3	59	27	37	2.6
1959	106.5	76.2	91.4	75	29	..	2.9
Mean	107.8	74.8	91.3	64	25	..	2.8

[a] 1957, July 2 through September 9; 1958, June 30 through September 21; 1959, June 29 through September 20.

Analysis of variance (Snedecor, 1956) indicated a highly significant ($P<0.01$) increase in average daily gain with shaded wallows. The pigs gained at a significantly ($P<0.05$) faster rate in 1957 than in either of the other years. There were no significant differences in carcass yields either between years or between treatments. The backfat thickness was significantly ($P<0.01$) greater for the shaded-wallow hogs than for the unshaded group in 1959. Analysis of variance of the feed consumption data by pen and by fourteen-day periods for 1958 and 1959 revealed a highly significant ($P<0.01$) difference in average daily feed consumed in favor of the shaded-wallow groups.

Rectal temperatures and respiration rates were obtained several times during the 1958 and 1959 trials when ambient air temperatures were between 104° and 107° F. The mean values for rectal temperature were: shaded wallow, 103.4° F. (range, 102.4 to 104.0° F.); sun wallow, 104.4° F. (range, 102.6 to 105.8° F.). Respiration rates were: shaded wallow, 49 per minute (range, 22 to 94); sun wallow, 124 per minute (range 70 to 184).

Twenty-four-hour behavior studies were conducted in 1958 and 1959. During these studies each hog was observed once every 15 minutes and

TABLE 2. ANIMAL RESPONSE TO SHADED AND UNSHADED WALLOWS

Treatment	1957		1958		1959		Mean[a]	
	Unshaded wallow	Shaded wallow	Unshaded wallow	Shaded wallow	Unshaded wallow	Shaded wallow	Unshaded wallow	Shaded wallow
Number of pigs	5	5	8	8	8	8	..	..
Length of trial, days	70	70	84	84	84	84	..	..
Av. initial weight, lb.	84	84	89	91	80	81	84	85
Av. total gain, lb.	95	104	101	110	92	118	96	111
Av. daily gain, lb.	1.36	1.48	1.20	1.31	1.10	1.40	1.20	1.38
Av. daily feed, lb.	5.75	6.68	5.17	5.92	4.39	5.60	5.06	6.03
Feed per 100 lb. gain, lb.	423	451	429	452	399	400	417	433
Yield,[b] %	....	....	69.3	69.9	68.2	68.3	68.8[c]	69.1[c]
Av. backfat, in.	....	....	....	....	1.4	1.6	....	....

[a] Weighted means.
[b] Warm packer style carcass weight divided by the final experimental weight.
[c] 1958 and 1959 hogs.

his use of the wallow was recorded. The results are shown in figure 1. The behavior patterns were similar each year. During the hot part of the day, 10 a.m. to 5 p.m., the shaded wallow was used as a cooling aid 90% of the time, whereas the unshaded wallow was used less than 25% of the time. The reason for this difference in use is undoubtedly partly due to the animals being exposed to the sun and to the higher temperature of the water in the unshaded wallow. As shown in figure 2, the water in the shaded wallow averaged 10° F. cooler than the water in the sun wallow during a typical 8-hour period in 1959. Spot checks of wallow

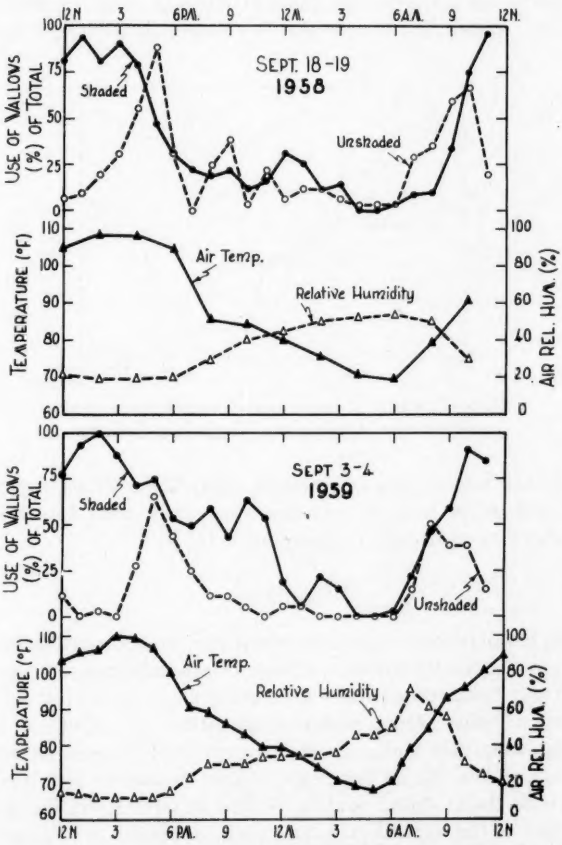

Figure 1. Effect of shade and air temperature on the use of water wallows by fattening hogs.

water temperatures during the hottest part of the day throughout the experiments indicated consistent temperature differences of 10° F. or over. Under these circumstances of high water temperatures (95° F. and over) and exposure to the sun, the pigs would remain in unshaded wallows only long enough to get wet, and would then retire to the shade until dry. The process would then be repeated. A study of the behavior patterns indicated the use of the unshaded wallow increased between 5 and 6 p.m. At that time the water temperature was still high, but radiation from the sun was reduced. This would indicate that the sun as well as the warmth of the water restricted the use of the unshaded wallow.

The results are different from those of Heitman *et al.* (1959) in which an ordinary wallow in the sun was as effective as a shaded wallow for

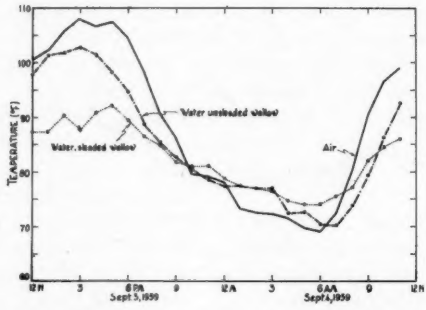

Figure 2. Effect of shade and air temperature on the temperature of water in concrete hog wallows.

increasing the rate of gain of fattening pigs. The contrast can probably be explained on the basis of the more severe heat stress during the trials reported here—a mean daily temperature of 91° F.

Summary

Results obtained over 3 years in which comparisons were made of pigs' response in a naturally hot environment (mean daily temperature 91° F.) modified only by the use of either a shaded or unshaded wallow (all animals had access to other shade) indicated consistent and significant increases in average daily gain and daily feed consumption for pigs provided with the shaded wallow. Rectal temperatures and respiration rates were higher for pigs with the unshaded wallow. Wallow water temperature during the hottest part of the day (10 a.m. to 5 p.m.) averaged 10° F. lower in the shaded wallow. Comparatively little use was made of the unshaded wallow after the water temperature reached 95° F.

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MOTILITY OF BOAR SPERMATOZOA AS INFLUENCED BY SEMEN FREEZING PROCEDURES

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AN efficient program of swine artificial insemination may be possible and practicable if improved methods of semen preservation can be developed. Freezing and storage at sub-zero temperature may be a method of preserving boar semen for prolonged periods.

One of the earliest reports of the freezing of semen was by Davenport (1897) who reported the survival of human spermatozoa after exposure to a temperature of —17° C. Reports published by Jahnel (1939), Luyet and Hodapp (1938), Hoagland and Pincus (1942), Shaffner (1942) and Polge and Rowson (1952) have shown that several types of mammalian spermatozoa are viable after freezing.

In the preparation of semen for cooling, glycerol is usually added to the diluter. Holt (1953) found that the addition of glycerol did not have any detrimental effects on bovine spermatozoa in the diluted state. In fact, he was able to demonstrate an increase in the conception rate of cattle when 10% glycerol was added to bull semen diluted with egg yolk citrate. Lovelock (1953) has theorized that glycerol action in diluted semen may be two fold: a modification of ice crystal formation, and the prevention of the accumulation of harmful electrolytes due to cellular dehydration.

In a comprehensive study of bovine semen freezing, Miller and Van Demark (1954) found that optimal glycerol concentration was between 5 and 6% at 4.5° C. No significant differences could be found between semen cooling rates of 1°, 2° and 4° C. per minute.

Polge (1956) was not able to induce pregnancy in sows by artificial insemination with semen that had been frozen and had only 25% motility when thawed.

In the present study, methods of processing semen, applicable to the cooling and storage of boar spermatozoa at sub-zero temperatures, were investigated.

Experimental Procedure

Five studies involving cooling rates, glycerol addition, equilibration times and temperature relationships were conducted. Two Berkshires, two Yorkshires and one Yorkshire-Duroc cross boar were used for the collection of semen. Each boar was ejaculated one or two times per week by

[1] The paper has been approved by the Station Director.

means of an artificial vagina and a dummy sow. The type of diluter and dilution rate were standardized in all studies. Freshly collected ejaculates were filtered to remove the gelatinous fraction of the semen. The semen filtrate was diluted with a solution of 30% egg yolk and 3% glucose (Dzuik, 1958) at the rate of $5x10^7$ spermatozoa per milliliter. Semen was microscopically evaluated for the percent of motile spermatozoa and the rate of progressive spermatozoan motility. Percent motile sperm was given a rating of 0–100 whereas progressive motility rate was evaluated through a range of 0–10. Diluted semen was frozen in 50-ml. heat-resistant serum bottles and thawed in water at 5° C. prior to evaluation.

In the first study the effect of decline in temperature on spermatozoan motility was observed. Boar semen was diluted with the standard extender, described above, containing 6% glycerol and allowed to stand (equilibrate) at 5°–6° C. for 4 hours. The diluted semen was transferred to 50-ml. heat-resistant serum bottles and placed in an alcohol bath which had been previously adjusted to 5° C. with dry ice. The temperature of the alcohol bath was gradually reduced from 5° C. to —15° C. in 45 minutes. When the bath temperature reached —15° C., sufficient dry ice was added to reduce the temperature rapidly to —70° C. During the process of cooling the semen from 5° C. to —70° C., samples were withdrawn from the bath at 5, —5, —15, —25, —35 and —70° C. and microscopically evaluated.

In the second study, the effects of three different storage conditions on spermatozoan motility were investigated. Semen was diluted with the extender containing 6% glycerol, equilibrated for 4 hours, cooled from 5° C. to —15° C. in 45 minutes and frozen rapidly to one of three storage temperatures, —23°, —72° or —95° C. These storage temperatures were maintained by a standard deep freeze, a Dry-ice chest and a two-phase ethane-freon 22 mechanical unit. Portions of the frozen samples were stored under each storage condition for either 1 or 7 days.

The effect of glycerol-treated diluter on spermatozoan motility was also measured. Freshly collected ejaculates were divided into two equal parts: one was diluted with the standard extender, and the other with the standard extender containing 6% glycerol. The glycerol-treated portion and the corresponding control sample were stored at 5° C. The semen was evaluated after 0, 1, 2, 3, 4, and 24 hours of storage.

The influence of equilibration time on spermatozoan motility was also studied. Fresh ejaculates were diluted with the extender containing 6% glycerol. Aliquot portions were allowed to equilibrate at 5° C. for 0, 4 and 24 hours before extending cooling. Each of the equilibrated samples was cooled to —70° C. then stored at —95° C. for one day.

The final study of the series consisted of measurement of the effects of various cooling rates on spermatozoan motility. Ejaculates were diluted with the standard extender containing 6% glycerol and equilibrated for 4 hours at 5° C. Samples were cooled concurrently from 5 to —15° C. within 15, 30, 45, 60, 75 or 90 minutes. Each bath was rapidly cooled

when the temperature reached —15° C. Semen was transferred from the bath at —70° C. to the mechanical storage unit, maintained at —95° C. and stored for one day.

Results and Discussion

When semen was withdrawn from the alcohol bath during the cooling process a progressive reduction in the percent motile sperm and spermatozoan motility rate was noted with each decrease in temperature, ranging from 5° C. to —70° C. The evaluation means are presented graphically in figure 1. Although reduction in the percent of motile sperm and motility rate were relatively constant when the bath temperature was decreased, a greater degree of reduction was noted when the temperature was lowered more rapidly from —15° C. to —70° C. By a t test, the greatest mean differences for both evaluations were highly significant ($P<.01$). Thus, there is evidence that boar semen does not possess sufficient protective factors to withstand rapid cooling at sub-zero temperatures. From these results it is apparent that further investigations of cooling rates and

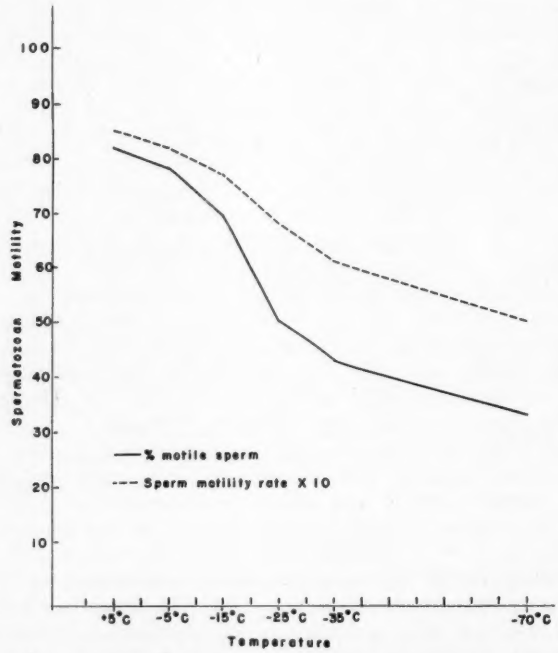

Figure 1. Evaluation means of diluted semen withdrawn from the alcohol bath at +5, —5, —15, —25, —35 and 70° C.

TABLE 1. EVALUATION MEANS OF DILUTED SEMEN STORED AT THREE DIFFERENT SUB-ZERO TEMPERATURES FOR 1 AND 7 DAYS[a]

	−23° C.[b]		−72° C.[c]		−95° C.	
Storage	1 day	7 days	1 day	7 days	1 day	7 days
Motility, %	13.8	2.3	30.1	17.6	30.3	20.0
Motility rate (0–10)	2.2	0.3	4.3	2.6	4.3	3.1

[a] The above means were derived from 30 individual ejaculates used in each treatment.
[b] The differences between evaluation means of semen stored at the two colder temperatures and −23° C. were highly significant ($P<.01$) at 1 and 7 days.
[c] The differences between evaluation means of semen stored at −72° C. and −95° C. were not significant at 1 and 7 days ($P>.05$).

the supplementation of low temperature resistance in boar semen diluters are warranted.

A summary of the data of the second study of three different sub-zero storage conditions is shown in table 1. The difference between the evaluation means of semen stored at −72° C. and −95° C. were tested by the *t* test for significance. No significant difference was found between the evaluation means of semen stored at these two temperatures for either 1 or 7 days of storage. ($P>.05$). However, when the mean differences between evaluations of semen stored at −23° C. and either −72° C. or −95° C. were tested, the evaluations of semen stored at the two lower temperatures were both significantly higher at 1 and 7 days of storage than the evaluation means of semen stored at −23° C. ($P<.01$). Although not investigated, longer terms of storage at the two lower temperatures may possibly result in larger differences in spermatozoan motility. A study by Etgen (1957) showed that higher spermatozoan motility resulted when frozen bull semen was stored at −95° C. rather than at −72° C. for prolonged periods. It is possible that sub-zero equipment, used to maintain refrigeration temperatures of −72° C. and −95° C., may provide more constancy in temperature below critical ranges than that used to maintain warmer storage temperatures.

Evaluation means of semen diluted with extenders containing either 0 or 6% glycerol are presented in table 2. No significant differences were

TABLE 2. EVALUATION MEANS OF SEMEN DILUTED WITH EXTENDERS CONTAINING 0 AND 6% GLYCEROL[a]

Percent glycerol	0 hr.		1 hr.		2 hr.		3 hr.		4 hr.		24 hr.	
	%M.[b]	M.R.[c]	%M.	M.R.	%M.	M.R.	%M.	M.R.	%M.	M.R.	%M.	M.R.
0	84.6	8.5	82.3	8.3	78.8	7.9	75.0	7.7	73.6	7.5	59.5	6.3
6	84.8	8.5	82.8	8.1	78.3	7.9	76.1	7.6	72.6	7.5	57.5	5.9

[a] The above means were derived from 30 ejaculates used in each treatment.
[b] Percent motile sperm was evaluated from 0–100.
[c] Spermatozoan motility rate was evaluated from 0–10.
[d] The differences of evaluation means of semen diluted with extenders containing 0 and 6% glycerol were not significant ($P>.05$).

TABLE 3. EVALUATION MEANS OF DILUTED SEMEN EQUILIBRATED FOR 0, 4 OR 24 HOURS BEFORE COOLING THEN STORED AT −95° C. FOR 1 DAY[a]

Equilibration time prior to freezing, hours	0	4	24[b]
Motile sperm, %	21.1	22.8	27.1
Motility rate (0–10)	3.5	3.8	4.5

[a] The above means were derived from 30 individual ejaculates used in each treatment.
[b] The differences in the evaluations of diluted semen, equilibrated for 0, 4 and 24 hours were not significant (P>.05).

found when evaluation means were compared (P>.05). These data indicate that boar semen may be diluted with as much as 6% glycerol, in preparation for freezing, without observable detrimental effects during the prescribed equilibration time used for processing bull semen. The results of the study agree favorably with the findings of Holt (1953).

The one-day evaluation means of semen equilibrated in three different ways are presented in table 3. The lack of significant differences between 0-, 4- and 24-hour equilibration times before freezing indicates no particular advantage of the longer equilibration time (P>.05). It is possible that the effects of freezing boar semen may be severe regardless of the equilibration time. The data in table 2 indicate that freezing procedure is more responsible for the relatively low survival of boar spermatozoa than the length of time semen is exposed to 6% glycerol before freezing.

Evaluation means of semen cooled at various rates are presented in table 4. The differences between 45-, 60-, 75- and 90-minute cooling rates were tested statistically by an analysis of variance (one-way classification). No significant differences were revealed (P>.05). The evaluation means for the 15- and 30-minute rates were significantly lower than the evaluation means of semen cooled at the four slower rates. From these data, no advantage was gained by extending the cooling time to periods longer than 45 minutes.

TABLE 4. THE EVALUATION MEANS OF DILUTED SEMEN COOLED AT VARIOUS RATES FROM +5° C. TO −15° C.[a]

Rate of cooling,[b] min.	15[d]	30	45[c]	60	70	90
Motile sperm, %	13.0	21.0	29.6	27.0	25.8	28.3
Motility rate (0–10)	2.9	3.7	4.5	4.4	3.9	4.1

[a] The above means were derived from 60 individual ejaculates for each treatment.
[b] Samples were stored at −95° C. for 1 day.
[c] The differences between the evaluation means of semen cooled within 45, 60, 75 and 90 minutes were not significant (P>.05).
[d] The differences in the evaluation means of samples cooled within the 15 and 30 minutes were significantly lower than samples cooled at the four slower rates (P<.05).

Summary and Conclusions

The influence of semen processing and storage conditions on pre- and post-freeze spermatozoan motility was studied.

When semen samples were withdrawn from the cooling bath at different temperatures, evaluations revealed that the percent motile spermatozoa was reduced at a faster rate at temperatures ranging from —15° C. to —25° C. than at other temperatures. Spermatozoan motility rate declined the greatest between —35 and —72° C.

Spermatozoan motility was maintained more efficiently at storage temperature of —72° and —95° C. than at —23° C. No significant differences were found in the motility of spermatozoa of samples of semen that had been equilibrated for 0, 4 and 24 hours prior to freezing. The frozen samples were stored at —95° C. for 1 day. When the semen diluter contained 6% glycerol, no detrimental effects on spermatozoan motility was noted over a 24-hour storage period at 5° C.

When semen was cooled from 5° C. to —15° C. within 15, 30, 45, 60, 75 and 90 minutes, the four slower rates resulted in a greater percent of motile spermatozoa and a higher motility rate after storage at —95° C. for 1 day.

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ENZYME SUPPLEMENTATION OF BABY PIG RATIONS CONTAINING DIFFERENT SOURCES OF CARBOHYDRATE AND PROTEIN [1]

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THE inability of the baby pig to utilize effectively certain ingredients commonly used in swine rations is well recognized. This may be partially attributed to a deficiency of various digestive enzymes which has been reported to exist in baby pigs for varying lengths of time (Lewis *et al.*, 1955; Kitts *et al.*, 1956; Bailey *et al.*, 1956; Hudman *et al.*, 1957).

Attempts to correct or alleviate this enzyme insufficiency by supplementing the ration with various digestive enzymes have resulted in both negative and positive responses. Cunningham and Brisson (1957) reported that neither proteolytic nor amylolytic enzyme supplementation improved the growth rate of two-day-old pigs; with six-pound baby pigs Lewis *et al.* (1955) reported that proteolytic enzyme supplementation improved weight gains and feed efficiency.

Since many of the previous studies used purified or semi-purified ration ingredients, this study was designed to evaluate the effects of supplementing rations composed of more commonly used ingredients with various enzymes.

Experimental

All pigs in this study were allotted to the treatments on the basis of weight and breed. They were housed in concrete-floored pens and allowed feed and water *ad libitum*. The data were analyzed statistically according to procedures described by Snedecor (1956) and by Duncan (1955). The composition of the basal ration for each trial is presented in table 1.

Trial 1. Fifty 11-day-old pigs were allotted to five replicated pens of five pigs each. They remained on experiment for a 28-day period. The five treatments consisted of the three rations shown in table 1 plus supplementation of the sugar-corn ration with 1% diastase (1:25) and a combination of 1% diastase and 0.5% Ethomid C/15.

Trial 2. Fifty pigs weaned at an average age of 11 days were allotted to five ration treatments. Each ration treatment was replicated, and the trial was for a 28-day period. The ration treatments consisted of the sugar-basal, sugar-basal plus a mixture of 1% pepsin (1:3000) and 1% pancreatin (1:25), sugar-corn basal, sugar-corn basal plus the 1% pepsin

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[2] Department of Animal Husbandry and Nutrition. The authors wish to acknowledge the Cudahy Laboratories, the Nulomoline Division of American Molasses Co., and American Cyanamid Co. for products used in this study.

and 1% pancreatin mixture, and the sugar-corn basal plus a combination of 1% pepsin, 1% pancreatin and 0.1% Ethomid C/15.

Trial 3. Sixty pigs weaned at an average age of 11 days were allotted to six ration treatments. Each ration treatment was replicated and all pigs were fed for a 49-day period. Ration treatments consisted of the following: basal, basal plus 1% pepsin, basal plus 1% pancreatin, basal plus a combination of 1% pepsin and 1% pancreatin, basal plus a combination of 1% pepsin, 1% pancreatin and 0.5% sucrase, and basal plus 1% pepsin and 0.5% sucrase. After 21 days, enzyme supplementation was discontinued

TABLE 1. COMPOSITION OF BASAL RATIONS[a]

	Trial 1			Trial 2		Trial 3	Trial 4	
Ration designation	Sugar	Corn	Sugar + Corn	Sugar	Sugar + Corn	Sugar	Dried skimmilk	Feather meal
Ingredients, %								
Sugar[b]	37.00	.....	18.50	40.00	21.50	40.00	19.26	27.15
Yellow corn	.....	37.00	18.50	.....	21.50	2.50	18.14	26.00
Dried skimmilk	40.00	40.00	40.00	.....	.....	.....	40.00	.....
Soybean meal	11.30	11.30	11.30	22.00	20.00	31.00	10.00	28.50
Poultry meal	.....	.....	.....	17.50	16.00	.....	.....	.....
Feather meal	.....	.....	.....	.....	.....	5.00	.....	5.00
Rolled oats	5.00	5.00	5.00	6.00	6.00	5.00	5.00	5.00
Dried whey	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Lard	....	....	....	7.00	7.50	2.00	2.00	2.00
Beet pulp	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00
Bonemeal	0.60	0.60	0.60	0.40	0.40	2.25	1.00	2.25
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Trace minerals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin-antibiotic premix[c]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00

[a] Diastase added as animal diastase (1:25); sucrase as powdered invertase, K=1.1 by A.O.A.C.; pepsin activity equal to pepsin N.F. 1:3000 and pancreatin, N.F. plus animal diastase activity 1:25.

[b] "C" grade sugar used in trials 1 and 2; "B" grade sugar used in trials 3 and 4.

[c] Contributed the following per lb. of ration: vitamin A, 2000 I.U.; vitamin D, 400 I.U.; niacin, 20 mg.; riboflavin, 3 mg.; pantothenic acid, 10 mg.; choline chloride, 500 mg.; thiamine, 3 mg.; folic acid, 3 mg.; pyridoxine, 1 mg.; vitamin B_{12}, 20 mcg.; chlortetracycline, 25 mg.; penicillin, 6 mg.; and streptomycin, 9 mg.

for one replication within each treatment. The pigs in the other replication continued on their initial treatments.

Trial 4. Sixty 9-day-old pigs were allotted to six replicated lots of five pigs each. The pigs were fed the following rations for a 49-day period: dried skimmilk basal (DSB), DSB supplemented with 0.5% diastase, and DSB supplemented with 0.5% diastase and 0.25% pepsin; feather meal basal (FMB), FMB plus 0.5% diastase, and FMB plus 0.5% diastase and 0.25% pepsin.

Results and Discussion

Trial 1. The results of this trial are presented in table 2. A comparison of the three sources of carbohydrates indicates that when dried skimmilk supplies the major portion of dietary protein, sugar serves most

TABLE 2. EFFECT OF DIASTASE AND ETHOMID C/15 SUPPLEMENTATION ON BABY PIGS FED RATIONS CONTAINING SUGAR AND CORN IN COMBINATION WITH DRIED SKIMMILK (TRIAL 1)

Treatment	Sugar	Corn	Sugar-Corn	Sugar-Corn+ Diastase	Sugar-Corn+ Diastase+ Ethomid C/15
Initial wt., lb.	7.30	7.30	7.20	7.00	7.20
Final wt., lb.	18.90	16.60	16.60	18.50	15.20
Av. daily gain, lb.	0.39	0.33	0.34	0.41	0.29
Av. daily feed, lb.	0.79	0.60	0.63	0.71	0.52
Feed/lb. gain, lb.	2.03	1.82	1.85	1.73	1.72

satisfactorily as the source of energy; the pigs fed the sugar-basal consumed more feed and gained faster, but were less efficient in feed utilization than those fed either corn or the sugar-corn combination.

Diastase supplementation of the sugar-corn basal improved both rate and efficiency of gain. The addition of both diastase and Ethomid C/15 adversely affected gain and feed consumption. This may be attributed to the high level of Ethomid C/15 since results obtained with a lower level (Trial 2) did not show an apparent palatability effect.

Trial 2. As shown in table 3 overall pig performance was similar for the two basal groups. The addition of pepsin and pancreatin to both the sugar basal and sugar-corn basal improved both rate and efficiency of gain; the largest response occurred with the sugar basal. The enzyme-Ethomid C/15 combination exerted an influence similar to that obtained with only enzyme supplementation.

The incidence of diarrhea was high throughout the trial and this coupled with their comparatively poor performance and physical appearance indicated that a combination of poultry meal and soybean meal was not a desirable source of protein for baby pigs. The consistent response to enzyme supplementation is in agreement with the work of Baker *et al.*

TABLE 3. BABY PIG RESPONSE AS INFLUENCED BY ADDING PEPSIN AND PANCREATIN WITH ETHOMID C/15 TO RATIONS CONTAINING POULTRY MEAL AND SOYBEAN MEAL IN COMBINATION WITH SUGAR OR SUGAR AND CORN (TRIAL 2)

	Sugar		Sugar-Corn		
Treatment	Basal	Pepsin+ Pancreatin	Basal	Pepsin+ Pancreatin	Pepsin+ Pancreatin+ Ethomid C/15
Initial wt., lb.	6.4	6.4	7.4	7.3	7.1
Final wt., lb.	12.9	16.1	13.6	14.6	13.6
Av. daily gain, lb.	0.23	0.35	0.22	0.26	0.24
Av. daily feed, lb.	0.55	0.65	0.54	0.53	0.54
Feed/lb. gain, lb.	2.48	1.90	2.60	2.38	2.31

TABLE 4. EFFECT OF SUPPLEMENTING BABY PIG RATIONS CONTAINING FEATHER MEAL AND SUGAR WITH COMBINATIONS OF PEPSIN, PANCREATIN AND SUCRASE FOR 21 OR 49 DAYS (TRIAL 3)

Treatment	Basal		Pepsin		Pancreatin		Pepsin+ Pancreatin		Pepsin+ Sucrase		Pepsin+ Pancreatin+ Sucrase	
Group number	I	II	I	II	I	II	I	II	I	II	I	II
Days on experiment	49	49	49	49	49	49	49	49	49	49	49	49
Days enzyme supplemented	0	0	21	49	21	49	21	49	21	49	21	49
Initial wt., lb.	9.0	9.7	10.7	10.1	10.6	10.5	11.0	11.7	10.5	11.8	11.2	10.4
21-day period												
Av. daily gain, lb.	0.14 (.14)[a]	0.14	0.18 (.18)	0.19	0.18 (.19)	0.21	0.24 (.23)	0.23	0.17 (.21)	0.26	0.24 (.20)	0.17
Av. daily feed, lb.	0.43 (.46)	0.50	0.47 (.50)	0.53	0.48 (.47)	0.46	0.51 (.51)	0.51	0.32 (.41)	0.50	0.43 (.43)	0.44
Feed/lb. gain, lb.	3.04 (3.31)[b]	3.58	2.61 (2.70)	2.80	2.68 (2.42)	2.16	2.13 (2.18)	2.24	1.90 (1.90)	1.90	1.76 (2.20)	2.64
49-day period												
Av. weight, lb.	42.1	36.4	40.7	43	38.7	41.8	42.6	42.6	40.9	44.6	43.9	40.9
Av. daily gain, lb.	0.74	0.60	0.69	0.75	0.65	0.73	0.75	0.73	0.69	0.78	0.77	0.69
Av. daily feed, lb.	1.42	1.10	1.40	1.38	1.23	1.34	1.51	1.34	1.25	1.46	1.41	1.28
Feed/lb. gain, lb.	1.93	2.02	2.04	1.84	2.04	1.84	2.10	1.85	1.80	1.87	1.83	1.73

[a] Average of I and II.
[b] Significantly different from all other treatments ($P<.05$).

(1956) who found that pigs with diarrhea increased in growth rate when pepsin was added to the ration.

Trial 3. The results of this trial are summarized in table 4. Since the pigs within a treatment were given the same ration for the first 21 days, the results for this period are presented both by groups and as averages of the two groups. A consistent response to enzyme supplementation was obtained in all instances. The pigs fed the pepsin-pancreatin combination gained most rapidly while those given the pepsin-sucrase mixture gained most efficiently.

Results of the 49-day period showed that withdrawal of the enzymes after 21 days exerted little influence on daily gains; an average of the daily gains for all pigs given enzymes for 21 days was 0.71 lb. as compared to 0.74 lb. for those continued on the various enzyme treatments. The

TABLE 5. RESPSONSE OF BABY PIGS TO RATIONS CONTAINING SUGAR IN COMBINATION WITH DRIED SKIMMILK OR FEATHER MEAL AS INFLUENCED BY DIASTASE AND PEPSIN SUPPLEMENTATION

	Dried skimmilk			Feather meal		
	1	2	3	4	5	6
Treatment	Basal	Diastase	Diastase +Pepsin	Basal	Diastase	Diastase +Pepsin
Initial wt., lb.	6.6	6.5	6.1	6.4	6.1	6.3
Final wt., lb.	43.9	45.7	46.2	35.5	33.6	37.0
Av. daily gain, lb.[a]	0.76	0.80	0.82	0.60	0.56	0.63
Av. daily feed, lb.	1.67	1.56	1.55	1.21	1.27	1.36
Feed/lb. gain, lb.	2.06	1.94	2.09	2.14	2.15	2.17

[a] Treatments 1, 2 and 3 significantly higher than treatments 4, 5 and 6 ($P<.05$).

average feed requirement per lb. of gain was 1.96 and 1.83 lb., respectively, for the 21- and 49-day enzyme supplemented groups.

Trial 4. The effect of diastase or a combination of diastase and pepsin on daily gains was negligible with both the dried skimmilk and feather meal rations (table 5). With the exception of Treatment 2, feed per lb. of gain was increased by enzyme(s) supplementation.

It is obvious that the pigs fed the dried skimmilk ration gained faster and more efficiently than those fed the feather meal ration. However, it is also evident that while optimum growth was not obtained with feather meal, the results of both trials 3 and 4 indicate that it may be used satisfactorily at the level of 5%.

The overall effect of supplementing baby pig rations containing various sources of carbohydrates and proteins with digestive enzymes was small as measured by improvements in rate and efficiency of gain. However, this response to enzyme supplementation was relatively consistent as evidenced by an increased growth rate over the controls in 11 of 12 instances and an improvement in feed efficiency in 9 of 12 comparisons.

Summary

Two hundred and twenty pigs weaned at 9 to 11 days of age were used to evaluate the effects of supplementing various type rations with digestive enzymes. Sugar and/or corn were used in conjunction with combinations of dried skimmilk, soybean meal, poultry meal and feather meal to form the major constituents in all rations.

There were no statistically significant differences in average daily gain between the control groups and the groups supplemented singly with diastase, pepsin and pancreatin or with various combinations of these enzymes; a similar situation existed when Ethomid C/15 or sucrase was combined with these enzymes. The differences in gain, while small, were consistently in favor of the enzyme supplemented groups.

Feed efficiency was significantly improved ($P<.05$) for a 21-day period by the addition of pepsin, pancreatin and a combination of the two with and without sucrase to a ration composed essentially of sugar, corn, soybean meal and feather meal. Although in general the differences between the control and treated groups were not statistically significant, feed efficiency in most instances was improved by enzyme supplementation.

The performance of pigs fed enzyme supplemented rations for 21 days was similar to that of pigs supplemented over a 49-day period.

Pigs fed rations containing a dried skimmilk-soybean meal combination gained significantly faster ($P<.05$) than those receiving a mixture of feather meal and soybean meal.

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EFFECT OF SPIRAMYCIN ON GROWTH AND FEED UTILIZATION OF YOUNG PIGS [1]

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SPIRAMYCIN, first described by Pinnert-Sindico (1954), is effective against gram-positive organisms. It is produced by *Streptomyces ambofaciens,* an organism isolated from a soil sample in Northern France. Pinnert-Sindico *et al.* (1954) and Boyd (1958a, 1958b) have reported on its pharmacological properties.

Kiser *et al.* (1959) reported that spiramycin at a level of 50 ppm. in the feed effectively controlled rather severe experimental infections of pleuropneumonia-like organisms (*Mycoplasma gallinarum*) in chicks.

The experiments reported herein were conducted to study the effectiveness of spiramycin in promoting body weight gains and enhancing feed utilization in young growing swine and to compare this antibiotic to other antibiotics, chlortetracycline or oxytetracycline, which have proven effective in the past.

Experimental

Experiment 1. Hampshire x Landrace crossbred and Landrace pigs initially averaging 26.3 days of age and 12.4 lb. body weight were used to evaluate five different ration treatments. The five ration variables consisted of a control, three levels of spiramycin (12.5, 25 and 50 gm./ton) and chlortetracycline at the level of 50 gm./ton. Eight replications of eight pigs per pen were used to evaluate each ration treatment. The 320 pigs were randomly allotted by weight from littermate outcome groups to their respective pens and the rations randomly assigned to pens within blocks of five pens each.

Before the experiment was begun the building was cleaned thoroughly and the pigs were weaned and then moved to the building directly from the sows.

Experiment 2. Two hundred and ninety-five Hampshire and Landrace pigs initially averaging 31.3 days of age and 12.5 lb. body weight were used to evaluate the same five ration variables as described in experiment 1, except that oxytetracycline, rather than chlortetracycline, was used as the 5th treatment. Five replications of 10 to 14 pigs each were used to evaluate each treatment. Contrary to experiment 1, all replications were not started on experiment simultaneously. Replications 1, 2 and 3 were

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started at weekly intervals and replications 4 and 5 were started the 4th week. The number of pigs used per pen was 12, 13, 14, 10 and 10 for replications 1 through 5, respectively. Allotment procedures were similar to those described for experiment 1.

Before the experiment was begun the individual pens were cleaned; however, the building was not completely empty of other pigs prior to or during the experiment.

Each of these experiments was conducted on commercial swine farms. Feed and water were consumed *ad libitum*. Rations were mixed and pelleted under the author's supervision by a commercial feed manufacturer. The composition of the basal ration is presented in table 1.

TABLE 1. COMPOSITION OF BASAL RATION

Ingredient	Pounds
Yellow corn (ground)	56.5
Solvent soybean oil meal (50% protein)	21.0
Dried whey (70% lactose)	15.0
Condensed fish solubles	2.5
Stabilized lard	2.5
Calcium carbonate	0.7
Dicalcium phosphate	0.95
Iodized salt	0.25
Vitamin–antioxidant premix[a]	0.35
Trace mineral premix[b]	0.20
Saccharin	0.05
Total	100.00

[a] Contributed the following per pound of complete ration: vitamin A, 2500 I.U.; vitamin D_3, 500 I.U.; riboflavin, 2.5 mg.; calcium pantothenate, 4.0 mg.; niacin, 20 mg. and vitamin B_{12}, 20 mcg. Butylated hydroxy toluene, 0.0125%.

[b] Contributed the following in p.p.m. of complete ration: Fe, 140.8; Cu, 9.6; Co, 3.2; Zn, 163.2 and Mn, 113.6.

The pen of pigs was considered the experimental observation in the analysis of the data according to procedures described by Snedecor (1956).

Results

Experiment 1. Each level of spiramycin improved gains as compared with gains of animals on the control diet, maximum gain occurring on those diets containing 50 gm. of spiramycin/ton. However, the response to spiramycin was beginning to plateau above 25 gm./ton. A similar response was noted for feed required per pound of gain and in this case the most efficient feed conversion was observed at the level of 25 gm./ton. The quadratic regression of both total gain and feed/gain on spiramycin level was statistically significant ($P=0.05$ or less).

Gains and feed required per pound of gain on the highest levels of spiramycin and chlortetracycline (50 gm./ton) were very similar. A Q-test

TABLE 2. THE EFFECT OF SPIRAMYCIN AND CHLORTETRACYCLINE ON WEIGHT GAINS AND FEED CONVERSION BY PIGS (EXPERIMENT 1)[a]

Treatment	Level of spiramycin (gm./ton)				Chlortetracycline (50 gm./ton)
	0	12.5	25	50	
No. pens /treatment[a]	8	8	8	8	8
No. pigs/treatment	64	64	64	64	64
Av. initial age, days	26.2	26.6	26.0	26.3	26.3
Av. initial wt., lb.	12.3	12.5	12.3	12.3	12.6
Gain, 1st 2 wks., lb	5.6	6.6	6.8	7.2	7.8
Total gain, lb.[b]	17.9	21.2	23.0	23.8	23.6[c]
Feed/gain, lb.[b]	1.90	1.84	1.64	1.70	1.78[c]

[a] On experiment 31 days, eight pigs per pen.
[b] Significant quadratic regression of gains and feed/gain on spiramycin levels.
[c] Difference in gains or feed/gain between 50 gm. chlortetracycline/ton and 50 gm. spiramycin/ton was not statistically significant.

(Snedecor 1956, p. 251) to analyze the differences in gains (23.8 vs 23.6) and feed/gain (1.70 vs 1.78) did not reveal statistical significance (table 2).

Experiment 2. Each level of spiramycin improved gains and feed conversion when compared with the performance of the animals on the control diet or the next lower level of the antibiotic. However, similar to the results of experiment 1, the gains and feed/gain tended to plateau above the 25 gm./ton level. The quadratic regressions of gains and feed/gain on spiramycin levels were statistically significant (P=0.01 or less).

The pigs gained faster (18.5 vs 16.2) and required less feed per pound of gain (1.83 vs 2.03) on the 50 gm./ton level of spiramycin than on the 50 gm./ton level of oxytetracycline. However, these differences were not statistically significant (P=0.05) when analyzed by the "Q-test" (table 3).

TABLE 3. THE EFFECT OF SPIRAMYCIN AND OXYTETRACYCLINE ON WEIGHT GAINS AND FEED CONVERSION BY PIGS (EXPERIMENT 2)

Treatment	Level of spiramycin (gm./ton)				Oxytetracycline (50 gm./ton)
	0	12.5	25	50	
No. pens/treatment[a]	5	5	5	5	5
No. pigs/treatment	59	59	59	59	59
Av. initial age, days	31.9	31.0	31.2	31.2	31.1
Av. initial wt., lb.	12.2	12.7	12.5	12.7	12.5
Gain, 1st 2 wks., lb.	3.4	4.6	5.3	5.4	4.8
Total gain, lb.[b]	10.6	13.5	17.6	18.5	16.2[d]
Feed/gain, lb.[c]	2.89	2.40	1.95	1.83	2.03[d]

[a] Replication 1 was on experiment for 28 days; other four replications were on experiment for 35 days.
[b] Significant quadratic improvement in total gains with increasing levels of spiramycin ($P<0.01$).
[c] Significant quadratic improvement in feed/gain on spiramycin levels ($P<0.01$).
[d] Differences (gain and feed/gain) between the 50-gm. level of spiramycin and oxytetracycline were not statistically significant.

Discussion

In each of the two experiments, increasing levels of spiramycin from 0 to 50 gm./ton improved gain and efficiency of food conversion. Maximum gain was not attained in either experiment. However, a significant quadratic regression indicates that further increases in the level of the antibiotic would result in smaller improvements in rate of gain.

In experiment 1, the most efficient feed conversion was observed for the 25 gm./ton level of spiramycin. In experiment 2, however, further increasing the level of antibiotic to 50 gm./ton resulted in further improvement in feed conversion. In each experiment, as in the case of the gain data, the quadratic regression of feed/gain on spiramycin levels was statistically significant, suggesting that the level required for maximum response was approached.

The percentage response to antibiotics was much greater in the second experiment than in the first. The 50 gm./ton level of spiramycin improved gains 33% in the first experiment, as compared with 75% in the second. Similarly the feed required per pound of gain was 11% less in the first experiment and 37% less in the second. This is probably a result of the difference in environmental conditions previously described. These observations are in agreement with those of Speer *et al.* (1950) and Catron *et al.* (1951) in that the cleaner the environment the smaller the response to chemotherapeutics. In addition to differences in sanitation, it should not be overlooked that differences in weather conditions, nutritional history and genetics of the animals and other factors contributed to the differences in over-all performance and possibly to the response to the antibiotics.

Summary

Two experiments involving 615 pigs were conducted to study the effect of varying levels (0, 12.5, 25 and 50 gm./ton) of spiramycin on rate of gain and feed conversion by young growing pigs, and also to compare the highest level with similar levels of chlortetracycline and oxytetracycline. In each of the experiments, maximum gains were obtained with the highest level of spiramycin fed. However, the statistically significant quadratic regression of gains on spiramycin levels is indicative of a plateauing of the response above levels of 25 to 50 gm./ton. Similar quadratic regressions of feed/gain on spiramycin levels were observed.

Differences in response (gain and feed/gain) to the 50 gm./ton level of spiramycin and the same level of chlortetracycline in one experiment and oxytetracycline in the other were not statistically significant.

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CARCASS CHARACTERISTICS OF SWINE AS INFLUENCED BY LEVELS OF PROTEIN FED ON PASTURE AND IN DRY LOT [1]

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SEVERAL experiments have been conducted to compare the performance of growing-finishing swine fed on pasture and in dry lot. Most of the early experimental research was conducted with rations that were lacking in vitamin and antibiotic supplementation. In these experiments the pigs fed on pasture tended to gain faster and more efficiently than those fed in dry lot. However, more recent research conducted by Hutchinson *et al.* (1955, 1956), Conrad and Beeson (1957) and Barnhart, Overfield and Lowry (1959) indicates that with supplemental vitamins and antibiotics, pigs fed in dry lot gained slightly faster than pigs fed on pasture.

Terrill (1954) indicated that the amount of protein needed for growing-finishing swine fed on good quality pasture was 2% less than for those fed in dry lot.

The experiment reported herein was conducted to compare the effect of well fortified corn-soybean oil meal rations containing 12% and 14% protein on carcass characteristics of swine fed on pasture or in dry lot.

Experimental Procedure

One hundred-sixty purebred Yorkshire, Hampshire, Duroc and cross-bred Yorkshire-Hampshire pigs were randomly allotted by weight outcome groups and breeding to five replications of four experimental treatments of eight pigs per pen. This experiment was designed as a 2x2 factorial with two rations calculated to contain 12% and 14% protein fed to growing-finishing pigs on pasture or in dry lot.

The pigs fed on pasture were confined to a pen of approximately 0.5 acre of good alfalfa pasture. A portable wooden house, 8′ x 12′, with a wooden floor was used for shelter and shade in each pen. The dry lot pigs were housed in a brick building with an opening to a concrete apron on the outside of the building. These pens were cleaned daily. Both groups of pigs were provided with automatic waterers and self-feeders. All pigs and feeders were weighed at two-week intervals. The feed conversion (feed per pound of gain) and average daily gain were calculated for 70 days

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(June 19 through August 28). The lighter pigs were continued on their respective rations until they reached market weight.

Ten crossbred barrows were selected at random from each experimental treatment for slaughter. The gilts from this experiment were kept as breeding stock. The dressing percentage, carcass length, carcass weight and backfat thickness were obtained from the carcasses. Average backfat thickness was calculated as an average of three measurements (first rib, seventh rib and last lumbar vertebrate). An estimate of the percentage of fat and lean in the carcass was calculated from a core sample taken from the carcass immediately posterior to the last rib, one inch laterally and parallel to the split surface of the carcass as described by Lu *et al.* (1958).

The composition of the experimental rations are presented in table 1.

TABLE 1. PERCENTAGE COMPOSITION OF EXPERIMENTAL RATIONS

Ingredient	12% protein ration	14% protein ration
Ground yellow corn	86.1	80.9
44% solvent soybean oil meal	7.0	12.2
50% meat and bone scraps	2.5	2.5
17% dehydrated alfalfa meal	2.5	2.5
Ground limestone	0.6	0.6
Steamed bone meal	0.2	0.2
Salt (iodized)	0.5	0.5
Trace minerals (high zinc, swine)	0.1	0.1
Vitamin-antibiotic premix[a]	0.5	0.5

[a] Contributed the following amounts of vitamins and antibiotics per lb. of complete ration: vitamin D_3, 90 I.U.; riboflavin, 1.0 mg.; niacin, 4.5 mg.; calcium pantothenate, 2.0 mg.; choline chloride, 105 mg.; vitamin B_{12}, 5.0 mcg.; and antibiotics, 5 mg.

Results and Discussion

A summary of the average daily gain and feed required per pound of gain is presented in table 2. All statements concerning statistical significance are made at a probability of 0.05 or less (Snedecor, 1956). The pigs fed a 14% protein ration in dry lot made a significantly greater average daily gain than the pigs fed on pasture, but not significantly greater than the pigs fed the 12% protein ration in dry lot. The average daily gain of both groups of pigs fed in dry lot (12% and 14% protein) was significantly greater than that of the pigs fed the 12% protein ration on pasture. Also, the average daily gain of the pigs fed in dry lot was significantly greater than the average daily gain (1.60 vs. 1.45) of those fed on pasture. The average feed required per pound of gain for pigs fed on pasture was significantly less than for the pigs fed in dry lot (3.04 vs. 3.29). There was no significant difference in the amount of feed required per pound of gain between protein levels within management systems. Lower average final weights and the consumption of alfalfa pasture may have contributed to the reduction in feed required per pound of gain for pigs fed on pasture.

The average daily gain and feed required per pound of gain for different protein levels across management systems were not significantly different. Also, there was no significant interaction between protein level and system of management indicating that pigs of this weight and age gained at a comparable rate and feed efficiency regardless of protein level within management systems. Therefore, with these well-fortified rations there was no evidence that pasture-fed pigs required a lower percentage of protein in their ration than dry lot fed pigs.

TABLE 2. RESPONSE OF GROWING-FINISHING SWINE FED 12 AND 14 PERCENT PROTEIN RATIONS ON PASTURE AND IN DRY LOT

	Dry lot		Pasture		
Treatment	12% Protein	14% Protein	12% Protein	14% Protein	Qs$\bar{x}$ [a]
Pens per treatment, no.	5	5	5	5	
Pigs per pen, no.	8 [b]	8	8	8 [b]	
Av. initial wt., lb.	64.1	64.2	64.2	64.4	
Av. final wt., lb.	173.6	177.4	163.8	166.4	
Av. daily gain, lb.	1.58	1.62	1.42	1.48	0.14
Feed per lb. gain, lb.	3.33	3.24	3.02	3.05	0.24

Treatment	Dry lot	Pasture	12% Protein	14% Protein
Pens per treatment, no.	10	10	10	10
Pigs per pen, no.	8 [b]	8 [b]	8 [b]	8 [b]
Av. initial wt., lb.	64.2	64.3	64.2	64.3
Av. final wt., lb.	175.5	165.1	168.6	171.9
Av. daily gain, lb.	1.60 [c]	1.45 [c]	1.50	1.55
Feed per lb. gain, lb.	3.29 [c]	3.04 [c]	3.18	3.15

[a] Difference required between treatment means for significance at P=0.05 or less.
[b] One pig was removed from one pen.
[c] Difference between means significant at P=0.05 or less.

The carcass data are summarized in table 3. The average final slaughter weight per treatment varied from 194.4 to 199.9 lb. and the average cold carcass weight per treatment varied from 134.4 to 142.9 lb. The pigs fed in dry lot had a higher dressing percentage than the pigs fed on pasture (71.68% vs. 69.83%) and those fed the 14% protein ration had a slightly higher dressing percentage than those fed the 12% protein ration (71.25 vs. 70.26). These differences were not statistically significant, nor was the difference in average carcass length between experimental treatments.

Pigs fed the 12% protein ration on pasture produced the thinnest backfat and the highest average estimated percentage of lean but differences were not significant. There was very little difference in backfat thickness and average estimated percentage of fat and lean between the protein levels. This finding is in agreement with the results of Crampton and

TABLE 3. COMPARISON OF CARCASSES OF GROWING-FINISHING SWINE FED 12 AND 14 PERCENT PROTEIN RATIONS ON PASTURE AND IN DRY LOT

	Dry lot		Pasture	
Treatment	12% Protein	14% Protein	12% Protein	14% Protein
Barrows per treatment, no.	10	10	10	10
Av. slaughter weight, lb.	198.8	199.9	194.4	199.0
Av. carcass wt., lb.	140.7	145.1	135.6	139.1
Av. dressing %	70.8	72.6	69.8	69.9
Av. carcass length, in.	29.4	29.3	29.3	29.3
Av. backfat thickness, in.	1.70	1.72	1.60	1.69
Av. estimated fat, %[a]	45.82	45.47	44.72	45.14
Av. estimated lean, %[a]	39.60	39.87	40.72	40.13

Treatment	Dry lot	Pasture	12% Protein	14% Protein
Barrows per treatment, no.	20	20	20	20
Av. slaughter weight, lb.	199.4	196.7	196.6	199.4
Av. carcass wt., lb.	142.9	137.4	138.2	142.1
Av. dressing %	71.7	69.9	70 3	71.2
Av. carcass length, in.	29.4	29.3	29.3	29.3
Av. backfat thickness, in.	1.71	1.64	1.65	1.70
Av. estimated fat, %[a]	45.64	44.76	45.10	45.30
Av. estimated lean, %[a]	39.74	40.42	40.16	40.00

[a] According to Lu *et al.* (1958).

Ashton (1946) and Ashton *et al.* (1955) who reported no significant difference in carcass quality of pigs consuming rations that varied only 2% in protein content. The pigs fed in dry lot seemed to be slightly fatter than the pasture-fed pigs as evidenced by a thicker backfat and a higher percentage of estimated fat in the carcass. These observations are in agreement with those of Whatley *et al.* (1959); however, they reported that a corresponding difference was not observed when the carcass backfat was measured on a sample of the pigs.

Summary

One hundred and sixty growing-finishing pigs were fed 12% and 14% protein rations on pasture and in dry lot. The pigs fed in dry lot made significantly greater gains and required significantly more feed per pound of gain than the pigs fed on pasture.

The level of protein did not significantly affect the average daily gain or feed conversion. The protein level x management system (pasture and dry lot) interaction was not statistically significant for rate of gain and feed conversion.

Ten barrows were randomly selected from each of the four experimental

treatments and slaughtered. Those fed on pasture had a slightly thinner backfat and less estimated carcass fat than those fed in dry lot. However, these differences were not statistically significant.

Level of protein did not significantly affect dressing percentage, carcass length, backfat thickness or estimated carcass lean or fat.

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RADIOGRAPHIC AND ELECTROCARDIOGRAPHIC STUDIES OF THE BOVINE HEART IN RELATION TO DWARFISM [1]

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THE problem of identifying individual animals heterozygous for the snorter dwarf gene has been attacked from many directions. The description and mode of inheritance of this defect has been reported by Johnson *et al.* (1950). Studies of bone abnormalities have been reported by Gregory *et al.* (1952), Emmerson and Hazel (1956) and Buchanan *et al.* (1956). Studies of blood constituents were conducted by Fransen and Andrews (1954), Foley *et al.* (1956) and Dollahon *et al.* (1959). Eveleth *et al.* (1956) reported on the occurrence of a beriberi type heart in the dwarf animal, and Buchanan (1957) indicated that a high proportion of the dwarf and carrier animals autopsied at the North Dakota station had this hypertrophy of the heart. The work reported here was undertaken to determine whether the heart abnormality might be diagnosed in the living animal and offer a means of differentiating between the homozygous normal and the heterozygous normal calves.

Experimental Methods

Radiographic Methods. In the spring of 1958 radiographs were taken of the hearts of 81 calves at the Antelope Range Field Station and of 26 calves at the Cottonwood Range Field Station. All calves were less than a week old. Radiographs of the heart were taken in the lateral, ventral-dorsal, and left- and right-posterior oblique positions. Figure 1 indicates the support built to hold the animal while the radiographs were taken. The left-posterior oblique appeared to surpass the others in ease of distinguishing the abnormal heart from the normal appearing heart.

The radiographic technique used was as follows:

1. The calf was raised by his front legs and strapped to the support while being held in the vertical position. The left-posterior oblique position was obtained by turning the back support approximately 45 degrees in the direction that placed the left side of the calf next to the film.
2. A Picker portable X-ray machine with a distance of 60 inches from tube to film was used.

[1] This study was conducted in cooperation with the Animal Husbandry Research Division, A.R.S., U.S.D.A. and the North Central Regional Project NC–1, The Improvement of Beef Cattle Through Breeding Methods. Approved for publication by the Director of the South Dakota Agricultural Experiment Station as Journal Series No. 473.

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3. Maximum kv.p. available varied from 65 to 75 with the rural line in use.
4. 15 ma. were used in all cases.
5. A non-grid cassette with high speed screens was used.
6. With these maximum settings an exposure time varying from 1.5 to 1.8 seconds was needed to obtain interpretable film.

The radiographs taken on the South Dakota Experiment Station cattle were used to establish a system of classifying hearts of different shape. From breeding histories of the cattle it was known that both heterozygous and homozygous normal calves should exist in the two herds. Since vertebral radiographs were currently being classified by the system developed at the Iowa station, a similar classification was adapted to the heart radio-

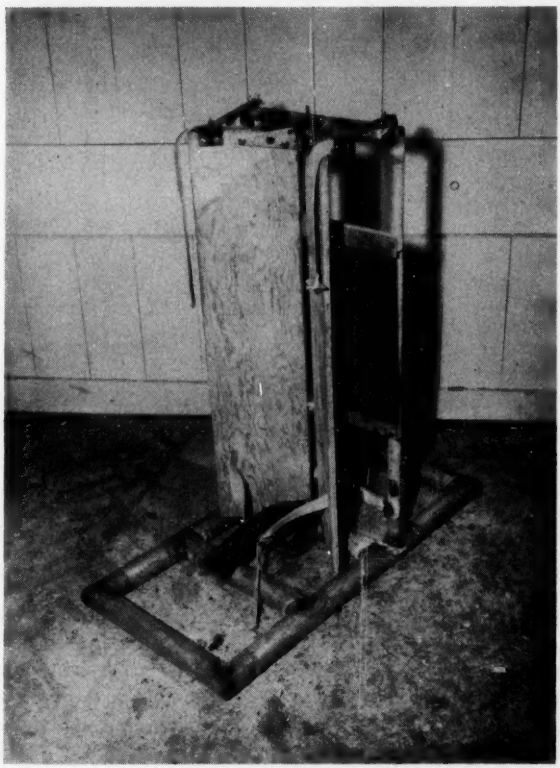

Figure 1. Apparatus used to restrain calf in position for X-raying.

Figure 2. Radiograph of normal or C type classification.

graphs in the following manner: C—Normal appearing heart (figure 2), B_4—Ovoid type heart (figure 3), B_8—Spheroid type heart (figure 4). The variations encountered between these type classifications were assigned intermediate value subscripts.

Since there were no known genotypes among the calves in the South Dakota Experiment Station herd, no test was available for this classification. Radiographs of 16 calves of known genotypes were taken in the Iowa Experiment Station herd during July 1958. These calves were older than the South Dakota calves, varying in age up to three months. In addition, 24 calves were X-rayed in a private herd in South Dakota during the same month. These calves were assumed to be clean or free of the dwarf gene from knowledge of their pedigree.

Electrocardiographic Methods. The electrocardiograms were obtained

with a Sanborn Model 70 battery operated instomatic cardiette. The leads used were I, II and III, corresponding to the bipolar limb leads of the human electrocardiogram with the forelegs corresponding to the human arms as suggested by Alfredson and Sykes (1942). The leads were attached to the forelegs and the left hind leg after clipping and liberal application of electrode paste. An intravenous injection of 37.5 mg. of perphenazine was given each calf at least 10 minutes prior to the test. Although all calves were not tranquilized to the same degree, there were no irregularities in the electrocardiograms which prevented interpretation.

The technique was applied to calves in the Iowa Experiment Station herd in July of 1959. Twelve pedigree-clean calves, 13 known carrier calves and 2 dwarf calves were used in the study. The calves were tested in random order. The calves varied in age from approximately 1 to 3 months, and prior to the test the pedigree-clean calves had been grazing in a pasture

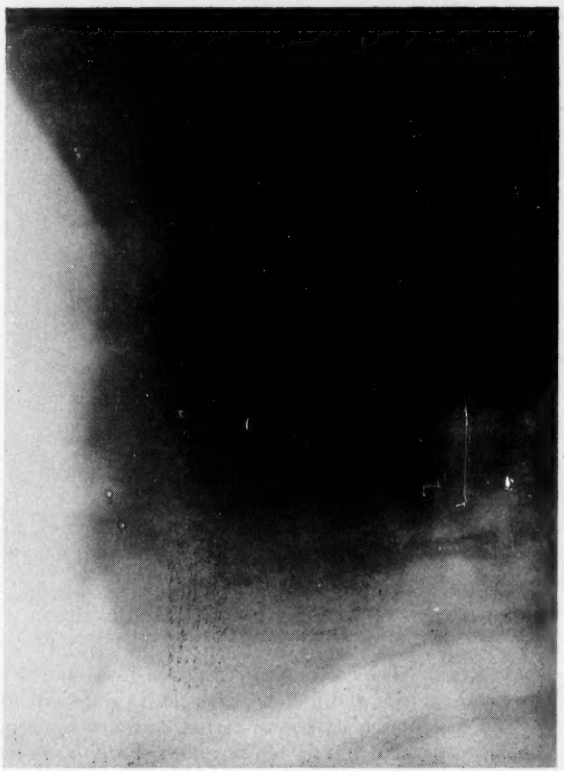

Figure 3. Radiograph of ovoid or B_4 type classification.

Figure 4. Radiograph of spheroid or B_8 type classification.

separate from the heterozygotes and dwarfs. The calves were sorted from their mothers early in the morning and remained separated until all electrocardiograms were completed at midafternoon.

The electrocardiograms were taken by the first two authors and interpreted by the third author who had no knowledge of the genotype or sex of the calves.

Experimental Results

Radiographic Results. The calves X-rayed at the Iowa station included six dwarf, six known carrier and four pedigree-clean calves. All six of the dwarf calves and four of the six known carrier calves were classified B_4 or greater as shown in table 1. Two of the known carrier calves and two of the pedigree-clean calves were classified normal. One of the pedigree

TABLE 1. CLASSIFICATION OF HEART SHAPE FROM RADIOGRAPHS FOR THREE GENOTYPES

Herd	Classification	Genotypes		
		Pedigree clean	Heterozygotes	Dwarf
Iowa	C	2	2	..
	B_2	1	..	..
	B_4	1	3	6
	B_7	..	1	..
Private S. Dak. herd	C	18	..	..
	B_2	2	..	..
	B_3	2	..	..
	B_5	1	..	..
	B_7	1	..	..
Two herds combined	C	20	2	..
	B_2	3	..	..
	B_3	2	..	..
	B_4	1	3	6
	B_5	1	..	..
	B_7	1	1	..

clean calves had the ovoid type heart and was classified B_4. The fourth pedigree-clean calf was classified B_2. The classifications of the radiographs of the 24 pedigree-clean calves in the private herd were 18 C, 2 B_2, 2 B_3, 1 B_5 and 1 B_7 (table 1).

Electrocardiographic Results. Examination of the electrocardiograms did not show an axis difference between the three genotypes, as shown in table 2. The left axis was predominant in the pedigree clean and heterozygous classes while the dwarf class was not represented sufficiently to evaluate.

The electrocardiograms were further evaluated for heart rate, QT interval, PR interval and QRS interval (table 3). Analyses of variance for these characteristics indicated non-significant differences between sexes and between genotypes. There was a highly significant sex-genotype interaction for the QRS interval. In spite of this significant difference the QRS interval does not appear to be useful in separating genotypes since 4 of the 25 normal phenotype calves in this study would have been classi-

TABLE 2. DISTRIBUTION OF LEFT, RIGHT, NORMAL AND QUESTIONABLE AXES AMONG GENOTYPES

Genotype	Axis			
	Left	Right	Normal	Questionable
Pedigree clean	6	0	1	5
Heterozygotes	7	1	0	5
Dwarf	1	0	0	1

TABLE 3. AVERAGE HEART RATE, QT, PR, AND QRS INTERVALS BY SEX AND GENOTYPE

	Pedigree clean					heterozygotes					Dwarf				
Sex	n	Rate	QT	PR	QRS	n	Rate	QT	PR	QRS	n	Rate	QT	PR	QRS
Male	2	141.5	0.20	0.11	0.05	10	145.6	0.23	0.12	0.04	1	145.0	0.25	0.12	0.04
Female	10	145.3	.23	.11	.04	3	139.0	.24	.12	.05	1	181.0	.20	.09	.03
Overall average	12	144.7	.22	.11	.04	13	144 1	.23	.12	.04	2	163.0	.22	.10	.04

fied in error. There was considerable uniformity within a class with the exception of the above mentioned four overlaps.

In evaluating the T waves it was found that an inverted or diphasic T-1 with an upright or diphasic T-2 was common. Variations encountered included inverted T-1 and 2, and diphasic T-3 in four of the calves. Three calves had all T waves upright. Fifteen calves had tall and peaked T-2 and 3. All of these characteristic waves were distributed approximately equally to the carrier and clean genotypes indicating that none of them would be useful in separating the two classes.

No important comparative data were found for rhythm, P waves, QRS waves or ST segments.

Discussion

The results of the radiographic studies, although based on few numbers, indicate that a relationship may exist between heart shape and genotype for the snorter dwarf characteristic. Twenty of the 28 pedigree clean calves were classified clean and 4 of the 6 known carriers were classified carrier (table 1). However, there is also a strong indication that this technique would be subject to classification problems and overlap of normal and abnormal types. There is an indication that the spheroid type heart as seen in the radiograph (figure 4) may not be associated with the dwarf syndrome. None of the 11 dwarf calves radiographed in the Iowa and South Dakota station herds had a classification greater than B_4, that of the ovoid heart. All of the dwarf calves had the typical ovoid heart shown in figure 3. The more extreme B_7 spheroid type heart occurred in the normal calves both carrier and clean (Iowa herd) in equal frequency, indicating that this anomaly may be unrelated to the dwarf syndrome.

The results of the electrocardiographic studies were negative with respect to separation of the carrier genotype from the homozygous normal genotype. In spite of the highly significant sex-genotype interaction for the QRS interval and the uniformity within a sex-genotype class, 4 of the 25 calves would have been misclassified on the basis of their QRS interval. Although based on too few numbers to give critical evaluation, these results do not indicate sufficient accuracy for the method to be useful.

Summary

Radiographic and electrocardiographic studies of the bovine heart were conducted in an effort to find a means of separating the normal appearing carrier of the snorter dwarf gene from the homozygous normal animal. Radiographs of the heart were taken on 28 pedigree-clean animals, 6 known heterozygous carriers, and 6 dwarf calves. Twenty of the 28 pedigree-clean calves were correctly classified by the radiographs, 4 of the 6 known carriers were correctly classified, and all 6 of the dwarf calves could be separated on the basis of their radiographs. The results of the electrocardiographic studies did not indicate an accurate means of separating the two genotypes although a highly significant sex-genotype interaction was found for the QRS interval. Although the numbers involved were too small for critical evaluation, it appears that the radiographic and electrocardiographic techniques used were not sufficiently accurate to furnish a practical means of separating the two genotypes.

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ABSTRACTS OF PAPERS PRESENTED AT THE MEETING OF THE WESTERN SECTION, A.S.A.P., JUNE 23, 24, 25, 1960, LOGAN, UTAH

1. A STUDY OF SINGLES AND TWINS UNDER TWO SYSTEMS OF REPLACEMENT EWE SELECTION. John A. Gorman and Lawrence C. Parker, *University of Wyoming, Laramie.*

One hundred and twenty breeding ewes were divided into two groups. All ewe lambs from both groups were kept for the years of 1955, 1956, 1957 and 1958. Performance data were collected on them through and including 1959. Each year at weaning time 50% of each group was selected as replacements. In Group I the selection was made by a visual appraisal of fleece and body characters. In Group II a selection index was computed and used as a basis of selection. The formula for the index was as follows: weaning weight + 2 x face score + 5 x type score + 5 x condition score + 5 x fleece score + length in centimeters x 7 for Fine, 6 for ⅜ Blood and 5 for ¼ Blood wool. For differences due to type of birth and varying age of dams, adjustments were made on body weight, type score and condition score. Body weight and wool length were corrected to 180 days. In Group I replacement ewes, for the 4-year period, there were 13% less ewes (twin birth) than were needed to give proportional representation; in Group II there were 14% less ewes (twin birth). Twins somehow should be given more consideration, for, at 3 years of age, differences in the body and fleece performance of twins in comparison to singles become much smaller.

2. DIFFERENTIAL GROWTH OF MALES AND FEMALES IN DIFFERENT YEARS. D. W. Blackmore, J. A. Marchello and J. J. Urick, *Montana State College, Bozeman.*

Data on weaning weight of Hereford calves born between 1930 and 1958 to 2- and 3-year-old first-calf heifers, were analyzed to determine factors to correct for sex difference. The analysis showed a highly significant sex-year interaction. Further examination showed 4 years in which the females exceeded the males in weaning weight. The differences were compared with those found in Holstein calves which also showed a highly significant sex-year interaction. The overall average of the males was 12 lb. greater for calves from 2-year-olds, and 22 lb. greater for calves from 3-year-olds. Two types of correction factors (one based on the average difference, the other on within year difference) were applied to each of the age groups (2-year-old and 3-year-old) which calved between 1941 and 1958. The data from each of the systems were analyzed to determine their effect on overall sex average, sex difference within years, and difference between years. Both gave the same overall average for the sexes after correction; the within year system of course removed sex differences within years, whereas the constant system decreased the difference in 10 of the years but actually increased the difference in 8 years. The constant system yielded greater between-year variance.

3. HERITABILITY OF 18-MONTH WEIGHT OF HEIFERS AND ITS RELATIONSHIP TO BIRTH WEIGHT AND WEANING WEIGHT OF THEIR FIRST CALF. J. A. Marchello, D. W. Blackmore and J. J. Urick, *Montana State College, Bozeman.*

The heritability of 18-month weight of heifers and the relationship of this weight to the birth and weaning weights of the heifer's first calf were studied in the Hereford experimental herd at the North Montana Branch Station over a 26-year period.

Heritability was estimated by the paternal half-sib correlation method and involved 481 animals. All heifer weights were corrected to 18 months of age by regressing weight on age. The effects of age at calving, years, and lines were removed by analysis of variance. The estimate of heritability of 18-month weight after adjusting for unequal subclasses was 0.36. Correlations between 18-month weight of heifers and birth and weaning weight of the heifers first calf were 0.27 and 0.24, respectively. This portion of the study involved 631 heifers and their first calves. Weaning weights were corrected for sex and age of calf, and birth weights were corrected for sex. Analysis of variance showed that the differences due to sex for both birth and weaning weight were highly significant. Furthermore, a highly significant sex-year interaction was found for weaning weights. Therefore, weaning weights were corrected for sex on a within year basis.

4. RELATIONSHIP BETWEEN MATURE SIZE, DAILY GAIN, AND EFFICIENCY OF FEED UTILIZATION IN BEEF CATTLE. Charlene R. Lickley, H. H. Stonaker, T. M. Sutherland and K. H. Riddle, *Colorado State University, Fort Collins.*

Data were taken from the records of the purebred Hereford herd of the Colorado Experiment Station. A phenotypic correlation of —.26 between daily gain and feed per pound gain was obtained from records of 417 yearling bulls. When feed per pound gain was adjusted for regression on initial weight, the correlation rose to —.45. Genetic correlations between daily gain and feed per pound gain were —.41 with actual feed per pound gain and —.69 with adjustment for initial weight. The genetic correlations between mature weight and daily gain and mature weight and efficiency were estimated by dam and son comparisons. The genetic correlation between mature weight and daily gain was 0.64, between mature weight and feed per pound gain, —.15. Heritability estimates computed by half sib correlations were: daily gain, $0.57 \pm .12$; feed per pound gain, $0.27 \pm .10$; feed per pound gain adjusted for initial weight, $0.36 \pm .11$; and mature weight, $0.72 \pm .22$. Selection for daily gain could be expected to increase efficiency and mature weight in approximately equal amounts. Selection for daily gain would be ¾ as effective in increasing efficiency as selection for efficiency itself and 1/3 as effective in increasing mature size as selection for mature size itself. Selection for mature size would be very effective in (genetically) increasing daily gain, $r_{P_{MW}G_{DG}} = 0.54$, but could not be expected to appreciably affect the genotype for efficiency, $r_{P_{MW}G_{E}} = -.12$.

5. UTILIZATION OF FROZEN SEMEN FROM YOUNG BEEF BULLS. S. W. Salsbury, P. O. Stratton and G. E. Nelms, *University of Wyoming, Laramie.*

A more direct approach to the selection of beef cattle for carcass desirability is needed. This study was undertaken to investigate one approach. Until a live beef animal can be evaluated accurately for carcass merit, it will be necessary to slaughter progeny for an evaluation of a sire. By freezing semen, slaughtering the bulls for carcass evaluation, then making selections, the progeny test can be avoided. Cows were inseminated with frozen semen collected by electro-ejaculation from beef bulls 12–14 months of age. Seventeen conceptions were obtained from 31 inseminations in the Angus and Shorthorn breeds and one conception from 29 inseminations in Herefords.

6. A SCORING SYSTEM TO EVALUATE LAMB RACKS. Marion Stanley, M. P. Botkin and C. O. Schoonover, *University of Wyoming, Laramie.*

Colored photographs were taken of the cross section of the rack at the 5th rib of 83 lamb carcasses. To obtain an indication of the desirability of rack and shoulder

cuts, standards were set up for scoring the racks for meatiness, conformation and amount of fat. The rack was separated from the shoulder between the 3rd and 4th ribs and from the loin between the 12th and 13th ribs. Standards were made by selecting five photographs each showing differences in these three traits which were used as criteria in scoring the other rack photographs. The selected photographs were enlarged, mounted on heavy paper and assigned numerical scores of 1 through 5. Specific gravity was determined on the 9-rib racks and a complete physical separation of the racks into lean, fat, bone, and skin and tendon was carried out. Simple correlations between total lean in the rack and cross-sectional area of the leg, of the rib-eye at the 12th rib, and rack meatiness score were found to be 0.71, 0.65 and 0.28, respectively. Specific gravity of the 9-rib rack was not related to the rack meatiness score (r=—.04). The angle of the ribs was measured on the carcass at the 5th rib and related to rack conformation and fat scores. These correlations were 0.41 and 0.46, respectively.

7. EFFICIENCY OF SOME DETERGENTS IN SCOURING GREASE WOOL. L. C. Parker, *University of Wyoming, Laramie.*

Fourteen detergents were donated in sufficient amounts by interested companies for trial runs on four different grades of wool in the Wyoming three (3′ x 12′) bowl scouring system. There has been some difficulty in the past in producing a scoured wool with a uniformly low residual grease content of not over 1.5%. The detergents were used according to the companies' recommendations on greasy wool all from the same flock. Scoured wool samples were tested for residual grease, ash, and vegetable matter, and for physical abnormalities of color and handle. Two samples were over 1.50% (3.68% and 1.59%) in residual grease; two were low, 0.92% and 0.90%; and the other 10 fell within the range of 1.32 to 1.44%. The average residual grease of the 64 tests was 1.42%. No color differences were discernible by visual examination. Three detergents produced harsher handling scoured wool than the rest. Based on these results it appears that all but two of the detergents have good scouring efficiency.

8. AN EVALUATION OF THE "SQUEEZE MACHINE" AND OTHER METHODS OF ESTIMATING CLEAN FLEECE WEIGHT. D. A. Price, S. K. Ercanbrack and L. O. Wilson, *U. S. Department of Agriculture, Dubois, Idaho.*

Whole clean fleece weights were obtained from 220 yearling ewes at the U. S. Sheep Experiment Station. Side sample estimates of clean fleece weights were determined on an additional 1673 yearling rams and 2488 yearling ewes. The data were classified within sex into fine, ½, ⅜ and ¼ blood wool grades. Correlations between actual whole fleece clean weight and its various estimates, within sex and wool grade classes, ranged between 0.82 and 0.87 for the machine method, 0.88 and 0.95 for the side sample method, 0.84 to 0.93 for regression of clean weight on grease weight and 0.90 to 0.92 for the multiple regression on grease weight, staple length, body weight, spinning count, machine reading and crimps per inch. The partial regression coefficients were derived from observations on the 2488 ewes, using side sample estimate as the dependent variable. Analyses of the partial regressions of whole clean fleece weight on all other traits (except side sample estimate) showed that in the presence of information on grease fleece weight, machine reading, and staple length, none of the remaining traits, either alone or together, contributed significantly to the prediction equations. The contribution of staple length was significant only for the fine wool equation. In the presence of grease fleece weight, the contribution of machine reading was significant only for fine ($P<0.01$), ½ blood ($P<0.05$), and ⅜ blood ($P<0.10$) wools.

9. MODIFYING TISSUE LIPIDS BY ORAL AND INTRAVENOUS FAT ADMINISTRATION. V. R. Bohman, M. A. Wade, A. L. Lesperance and C. B. Wilson, *University of Nevada, Reno.*

Long yearling steers were used in a 3 x 3 Latin square experimental design to measure the effect of different methods of administering fat on the content of lipids in certain body tissues. The experimental treatments were: (1) grass hay only (control ration); (2) oral fat, ½ lb. of cottonseed oil fed once daily; and (3) injected fat, ½ lb. of cottonseed oil, "Lipomul", injected into the jugular vein once daily. The experimental period was 14 days long. Fat injection caused a large but temporary increase in plasma fat. Twenty-four hours after injection the plasma fat had returned to normal. Diurnal variations were not evident for plasma ketones, cholesterol, carotene or vitamin A. Allen fat and cholesterol increased with oral fat but not with injected fat during the 14-day period. Injected fat decreased plasma vitamin A and carotene. Liver fat and cholesterol were much higher in the injected animals than in those fed fat or the control ration. Liver carotene and vitamin A were not influenced by the treatments.

10. EFFECT OF PRE-BREEDING AND POST-BREEDING FEED TREATMENTS ON REPRODUCTIVE PHENOMENA OF RANGE EWES. Vic Hoxsey, A. S. Hoversland, D. W. Blackmore and J. L. Van Horn, *Montana State College, Bozeman.*

Two pre-breeding treatments with three winter treatments superimposed on each, were used to study the effect of feed level on various phases of reproductive performances. On November 5, 204 ewes, from three breeds, were weighed and allotted at random to the pre-breeding groups. One group received only range forage, the other received range forage plus 1 lb. per day of a 31% protein supplement. Two weeks later all were weighed again and rams were introduced. As soon as the ewe was marked she was transferred to one of the following: (a) slaughter 3 days after breeding, (b) fed winter range only, (c) fed winter range plus 1 lb. per day of 31% protein supplement, (d) fed grass hay according to appetite. The ewes on high pre-breeding feed shed 1.3 ova per ewe, had an estimated 12.5% pre-natal death loss, 84.1% of the ewes lambed, 11.6% twins. The corresponding values for the low pre-breeding feed level were 1.1, 7.6, 73.5 and 8.2. The three winter treatments showed: (a) range only, 81.1% of ewes lambed and 7.0% twins; (b) range plus supplement, 82.1% of ewes lambed and 15.2% twins; (c) grass hay, 73.2% of ewes lambed, and 7.3% twins.

11. FERTILITY STUDIES OF SHEEP IN SOUTHWESTERN WYOMING. PART I. PLASMA AND LIVER VITAMIN A LEVELS, SELENIUM LEVELS OF BLOOD CELLS AND LIVER AND KIDNEY TISSUES, CHEMICAL AND BOTANICAL ANALYSES OF RUMEN CONTENTS. J. W. Oxley, N. W. Hilston, P. O. Stratton, C. J. Kercher, W. W. Ellis, M. W. Glenn, J. W. Hamilton and R. L. White, *University of Wyoming, Laramie.*

Eighteen head of three-year-old ewes were selected at random from three typical range flocks representing herds of high, average, and low lamb production. Two ewes from each of the three sample groups were slaughtered at monthly intervals during February through April, 1957, and during September through January, 1958. Also two ewes from each of three herds representing three diverse summer range areas were sacrificed in August, 1958. Jugular blood and liver were analyzed for vitamin A; blood cells, liver, and kidney, for selenium; and rumen contents, for proximate and botanical composition. The mean plasma vitamin A estimated from

112 samples collected from 54 sheep was 42±1.1 mcg. per 100 ml. Liver vitamin A averaged 255 mcg. per gm. fresh tissue for the 40 head of sheep killed during the winter-spring and fall-winter periods, and 230 mcg. per gm. for the six livers collected during the summer period. There were no important differences in hepatic levels of vitamin A between herds or between months within the two seasons. Selenium tended to accumulate in the tissues as the winter grazing season progressed but was largely eliminated during the spring and summer grazing seasons. The proximate composition of the rumen contents was indicative, but not a reliable measure, of the dietary intake of the grazing animal. Botanical analyses of the rumen contents of six sheep revealed their diverse forage selectivity. This method was satisfactory for estimating the amount of grass or grass-like plants, browse, and forbs and in most cases for determining the exact species of the browse types of plants in the rumen contents.

12. FERTILITY STUDIES OF SHEEP IN SOUTHWESTERN WYOMING. PART II. INTERNAL PARASITISM; BODY WEIGHTS, LAMBING AND DRY EWE PERCENTAGES, WINTER AND SUMMER RANGE SURVEYS. J. W. Oxley, N. W. Hilston, P. O. Stratton, C. J. Kercher, M. W. Glenn and R. L. Lang, *University of Wyoming, Laramie.*

The second phase of a study of possible factors affecting lambing performance among the flocks of southwestern Wyoming involved observations on (1) the incidence of internal parasites, (2) body weights of the sample ewes at each collection period, (3) a three-year survey of sheep management practices and lambing and dry-ewe percentages, and (4) surveys of both the winter and summer range areas. The incidence of stomach worms (*Ostertagia* species) and fringed tapeworms (*Thysanosoma actinioides*) in all the sheep slaughtered suggested that these parasites did not affect the production of the sheep. Body weights of a sample number of ewes of similar age taken during gestation and prior to and during the breeding season were not directly related to the levels of fertility in the three herds sampled. Information on lambing and dry-ewe percentages and on management practices for the years 1956–1958 showed the need for future studies on the causes of the high incidence of barren two-year-old ewes. Range surveys indicated that there were greater differences among the three summer ranges in quantity and quality of forage than there were among the areas of the winter range. One area, a superior type of summer range, was grazed by the flocks with the highest lambing percentages. This observation might indicate that the fertility level of the sheep is related to the forage quality and/or that this range supports a higher percentage of older ewes, which tend to be more prolific and fertile.

13. RELATIONSHIP OF STOMACH GROWTH TO AGE IN THE YOUNG LAMB. Gordon L. Jessup, Jr., D. C. Church and Ralph Bogart, *Oregon State College, Corvallis.*

Sixteen lambs were slaughtered in groups of four each at 2, 4, 6, and 8 weeks of age. All lambs were sired by the same inbred Suffolk ram. Eight of the lambs were from ewes of three different inbred lines of Suffolks and eight were from Dorset x Columbia ewes. Each age group contained two males and two females. Live body weight and the wet weight, dry weight, and volume of the rumen, reticulum, omasum, and abomasum were studied. Volume was measured by means of a water manometer at a constant pressure of 1 in. of water. Growth rate of all four compartments was essentially linear. Rumen wet weight was significantly correlated with rumen dry weight ($r=.996$) and rumen volume ($r=.970$). Rumen and abomasum dry weights were significantly correlated ($r=.771$). Expressed as a percentage of the total dry weight of the four compartments, the abomasum averaged 46.8% at 2 weeks of age

and declined to 19.7% at 8 weeks; while the rumen averaged 35.9% at 2 weeks and increased to 63.7% at 8 weeks. Thus the correlation between rumen and abomasum dry weight expressed as a percent of total dry weight was —.986. Organ dry weight as a percentage of the wet weight was relatively uniform at all ages studied, and averaged 11.7%, 12.9%, 13.6%, and 11.2% for the rumen, reticulum, omasum, and abomasum, respectively. Rumen and reticulum weights (both wet and dry) expressed as a percentage of body weight increased with age, but omasum and abomasum weights remained relatively constant.

14. SOME ASPECTS OF THE SECRETION OF PAROTID SALIVA IN THE BOVINE. C. B. Bailey and C. C. Balch, *National Institute for Research in Dairying, University of Reading, Shinfield, Reading, Berkshire, England.*

An exteriorized right parotid papilla was prepared in a 450-pound Friesian steer calf. The saliva drained from this fistula into a rubber collecting apparatus attached to the animal's jaw. The rate of secretion from the fistulated gland was measured at approximately every five minutes starting immediately after the morning meal and ending immediately after the evening meal. In addition, two complete 24-hour collections of saliva were performed. The rate of parotid flow varied from 1.2 to 48 ml/min. Chewing on the side of the mouth containing the fistula was the most effective stimulus to saliva flow and evoked rates of secretion 2 to 4 times those during periods of rest. When the animal chewed on the unfistulated side of the mouth during rumination, the rate of secretion was raised little or not at all. When the animal chewed on the unfistulated side of the mouth during a meal the rate of flow was high to begin with but declined precipitously thereafter to give low values (about 2 ml/min.) at the end of the meal. Low rates of flow invariably followed periods of rumination. Exclusive of these very low values, the average rates of saliva secretion during periods of rest were higher long after a meal (about 20 ml/min.) than shortly thereafter (about 5 ml/min.). The mean rates of parotid saliva secretion during eating, rumination and rest were 20, 25, and 10 ml/min., respectively. During the two 24-hour periods, 21.9 and 23.8 litres of saliva were collected.

15. SOME EFFECTS OF SALT WATER ON GROWING CATTLE. H. J. Weeth, L. H. Haverland and D. W. Cassard, *University of Nevada, Reno.*

The effects of six levels of NaCl in the drinking water was studied with heifers. Levels of added NaCl were 0, 1.0, 1.25, 1.50, 1.75 and 2.0%. Two change-over experiments involved six animals each and 30-day treatment periods. The season was winter. Addition of 1.0% NaCl to water caused increased water consumption, but did not appear toxic. The safe tolerance level for salt water appeared to be near 1.25% NaCl. Heifers maintained body weight while drinking 1.50% NaCl water, but lost weight on 1.75 and 2.0%. Symptoms of toxicity were anorexia, anhydremia, depressed rectal temperature, and dryness of skin and feces. Heifers drinking 2.0% NaCl water had elevated serum sodium and potassium. In general, the symptoms of salt water toxicity resemble those of simple dehydration.

16. INFLUENCE OF INJECTION SITE ON BLOOD VITAMIN A AND CAROTENE LEVELS IN SHEEP. T. R. Varnell and E. S. Erwin, *University of Arizona, Tucson.*

Thirty-two wether lambs were divided into four groups and administered aqueous emulsions of carotene and vitamin A at a level of 1 mg. per lb. body weight. One half of each group was injected with carotene, the other half with vitamin A. Injections were intraruminal, intraperitoneal, intramuscular, and subcutaneous. Blood samples were withdrawn at 3- to 6-hour intervals over a 24-hour period, according to site of

administration. Average initial plasma vitamin A levels in animals receiving vitamin A injections by intraperitoneal, intramuscular, intraruminal, and subcutaneous routes were 35.2, 34.0, 35.6 and 41.9 mcg. %, respectively. At 3 hours, these levels of vitamin A increased to 83.7, 92.0, 40.1 and 59.9 mcg. %, and at 24 hours they were 46.4, 46.8, 48.6 and 44.7 mcg. %. Average plasma carotene levels in animals subjected to intraperitoneal, intramuscular, and subcutaneous carotene injections were 13.7, 23.6 and 18.0 mcg. % at 24 hours. Trace amounts of carotene appeared in plasma of animals subjected to intraruminal carotene injections. Plasma vitamin A levels in animals receiving intraperitoneal and intramuscular carotene increased from initial values of 28.7 and 26.1 mcg. % to 40.7 and 38.8 mcg. % at 9 hours, and at 24 hours they were 29.2 and 39.7 mcg. %, respectively. Plasma vitamin A did not increase in animals treated with intraruminal and subcutaneous carotene injections.

17. AMINO ACID EXCRETION PATTERNS OF NORMAL AND "RUNTY" PREWEANING PIGS. R. W. Mason, David C. England and Kraig Weider, *Oregon State College, Corvallis.*

Urine samples were collected at least once weekly for 2 months from five "runty" pigs and from five of their litter mates of normal size. Three litters were involved. One-tenth ml. of each urine sample was analyzed by two dimensional paper chromatography, and at least 12 unknown compounds which react with ninhydrin appeared. One of these compounds appears to be associated with slow growth rates. The chromatograms changed at weaning; in particular, two unknown compounds which give a yellow color with ninhydrin disappeared. Chromatograms of "runty" pigs differed from those of normal pigs even though, as would be expected, there was considerable variation in both normals and runts. The runts, in general, excreted excessive amino acids.

18. AMINO ACID EXCRETION PATTERNS OF WEANLING PIGS. R. W. Mason, David C. England and Kraig Weider, *Oregon State College, Corvallis.*

Weanling pigs were allotted to form two groups, each of five, with equal sex and litter representation. One group was allowed to eat *ad libitum* and the other was limited to 7 lb. of feed daily. Average initial weights were 26 lb. and 27 lb. Average total gain per pig during an 85-day period was 8 lb. for the limited-fed group and 42 lb. for the *ad lib.* group. Urine samples were collected weekly and analyzed for free amino acid concentrations by two dimensional paper chromatography. The chromatograms changed with progression of the experiment and the final urine samples revealed that in each sex-litter class the *ad lib.* pig had higher concentrations of ninhydrin-reacting substances. Cystine, glycine, valine, methionine, leucine and taurine were absent from the urine of all 10 pigs. In addition, proline and phenylalanine were absent from the urine of *ad lib.* pigs. Ornithine, arginine, histidine, tyrosine, tryptophan and an unidentified substance were absent from the urine of the limited-fed pigs. Other naturally occurring amino acids were present in different amounts. There were both qualitative and quantitative differences between litters. The fastest growing animals in both treatments in general had higher concentrations of amino acids in their urine than slower growing ones.

19. SERUM BINDING OF RADIOTHYROXINE IN SHEEP AND CATTLE. Clifton Blincoe and H. J. Weeth, *University of Nevada, Reno.*

In the measurement of the serum binding capacity of thyroxine, a strongly basic ion exchange resin competes with serum protein for radiothyroxine. The resin binds that radiothyroxine not bound by the serum proteins. Mitchell and O'Rourke (*J. Clin.*

Endo. Met. 18:1437–9, 1959) reported that the serum proteins of pregnant women bound more thyroxine than the serum proteins of non-pregnant women. The resin uptake of thyroxine-I^{131} was studied in bovine and ovine sera. It was found that these sera bound much more thyroxine than human sera. The resin uptake of thyroxine I^{131} is about 50% for women, 29±3% for dairy cattle and 22±2% for sheep. These differences are highly significant. No effect of first trimester pregnancy was found in sheep or cattle. Rambouillet, Columbia, and Hampshire ewes all bound the same amount of thyroxine. The standard deviation of analysis was ±1.7%.

20. FALLOUT I^{131} IN RENO CATTLE: MARCH 1959—MAY 1960. Clifton Blincoe, *University of Nevada, Reno.*

The I^{131} level of cattle passing through packing plants in Reno, Nevada, is monitored regularly. The only selection practiced is that samples are not taken from very young animals. The I^{131} content of a four-gram sample of the thyroid gland is measured with a well-type scintillation counter and pulse height analyzer. The narrow range of gamma-ray energies counted and the decay curve of the thyroid samples indicates that substantially all the activity measured is from I^{131}. During the substantially precipitation-free portion of 1959 and early 1960 the thyroids of these animals contained slightly less than one picocurie (micromicrocurie) I^{131} per gram of thyroid tissue. Since I^{131} has a half-life of 8.08 days, this constant level would indicate constant replenishment of the I^{131} content of animal feeds. Thus all I^{131} in the biosphere is not from nuclear explosions. During a protracted period of precipitation, the I^{131} content of the thyroid glands increased to a level of 4 picocurie I^{131} per gram of thyroid tissue and decayed to its initial level after the precipitation ceased. This rise was probably due to the "rain-out" of atmospheric I^{131}. Due to local weather conditions no increase in thyroid I^{131} was noted after the first test of a nuclear device by the French, but a transient increase in thyroid I^{131} was associated with their second test.

21. THE INFLUENCE OF AGING ON CALCIUM METABOLISM IN RATS. R. Hironaka, H. H. Draper and J. Kastelic, *University of Illinois, Urbana.*

Calcium absorption, endogenous excretion, and turnover rate of plasma calcium were compared in mature (10 to 12 months old) and aged (22 to 32 months old) male albino rats. Endogenous excretion of calcium was found by the principle of isotope dilution. True absorption was calculated from the values of endogenous excretion and calcium balance. Turnover rate of plasma calcium was estimated from the rate of decline of fecal calcium specific activity. The aged rats excreted more endogenous calcium ($P<0.05$) and absorbed more calcium ($P<0.05$) than the mature rats. A relationship existed between the absorption of calcium and total endogenous excretion plus calcium balance. The turnover rate of blood plasma calcium did not appear to be related to the rate of calcium absorption or to the rate of endogenous fecal excretion.

22. WEIGHT LOSSES SUGGESTING NUTRITIONAL EDEMA IN NEW-BORN CALVES. Wm. C. Van Arsdel III, Hugo Krueger and J. E. Oldfield, *Oregon State College, Corvallis.*

The average birth weight of 1956 beef improvement project calves was 70.3 lb. (males 73.4, females 66.8). Of 28 beef improvement calves weighed within one week of birth, only one showed a weight loss (1.0 lb., first day) and one showed no gain on the third day. These findings are consistent with other data on weight changes in beef cattle following birth, indicating that 90% of calves gain weight from day

of birth and that subsequent gain is essentially linear. The average birth weight of nine calves on the white muscle project (seven females) was 72 lb. Seven calves of the white muscle project showed a postnatal weight loss or a prolonged failure to gain weight; these calves had white muscle lesions on autopsy or electrocardiographic abnormalities. Two calves that gained normally had normal electrocardiograms and no indications of white muscle disease at autopsy. Of seven calves on the white muscle project, weighed within three days of birth, five showed weight losses of 4 to 7 lb.; while two as indicated showed normal gains. The other two white muscle project calves were weighed too late to demonstrate a postnatal weight loss, but the individual weight curves suggested an initial weight loss. After the early postnatal weight loss, calves that later showed white muscle at autopsy, gained weight at normal rates. Weighing animals for a period immediately following birth might prove valuable in identifying calves whose *in utero* environment has produced cardiovascular problems in the new born. Among these may be white muscle calves.

23. EFFECT OF AN INJECTED TRANQUILIZER ON IN-TRANSIT SHRINK AND FEEDLOT GAIN OF WEANER STEERS. David C. England and Norton O. Taylor, *Oregon State College, Corvallis.*

In experiment 1, 12 weaner steer calves averaging approximately 310 lb. were given intramuscularly the following amounts of the tranquilizing agent, tetrahydrozoline, per pound of body weight: none, 0.115 mg., 0.03 mg., and 0.015 mg. repeated. Injection was given as calves were separated from cows at the ranch. The calves were weighed, transported approximately 150 miles to a feedlot and reweighed approximately 40 hours after initial weights were taken at the ranch. The repeated injection of tranquilizer was given at the initial feedlot weighing. Average shrink per head during the 40 hours following treatment was 9, 2, 11 and 1.5 lb., respectively for the various treatments. Feedlot gains during the first 100 days were 1.45, 1.49, 1.48 and 1.51 lb., respectively. No behavior differences were apparent. In experiment 2, 12 weaner steer calves averaging 457 lb. were given the same treatments as above. Distance from ranch to feedlot was 75 miles; time between weight at ranch and first feedlot weight was approximately 60 hours. Average in-transit shrink per calf was 9, 22, 18 and 8 lb., respectively, for each treatment. Average daily gain from ranch weight to end of first 51 days in feedlot was 1.00, 1.06, 1.10 and 0.91 lb. per calf for each treatment, respectively. These differences are not statistically significant. In-transit shrink data are contradictory for the two experiments. Results of both experiments show no statistically significant effect of treatment on early feedlot gains.

24. TRANQUILIZERS FOR FAT BEEF CATTLE GOING TO SLAUGHTER. Conrad J. Kercher, *University of Wyoming, Laramie.*

Forty-eight, two-year-old fat steers were randomly divided according to their previous nutritional history into the following treatment groups: (1) controls; (2) 50 mg. of ethyl isobutrazine (Diquel) per 200 lb. body weight; (3) 50 mg. of ethyl isobutrazine per 100 lb. body weight; and (4) 1 mg. tetrahydrozoline per 100 lb. body weight. The steers were administered the tranquilizers intraperitoneally about 15 hours prior to shipment. They had access to alfalfa hay prior to shipment; however, water was removed six hours prior to loading. The steers were weighed individually just prior to loading. They were trucked 425 miles to slaughter and were in transit for 11 hours. The in-transit shrink and dressing percentage based on warm carcass weights and final feedlot weights were as follows: (1) 3.87%, 60.35%; (2) 4.09%, 60.68%; (3) 3.92%, 59.83%; and (4) 3.98%, 61.06%. These differences in shrink and dressing percentage were not significant. None of the carcasses of the steers was bruised.

25. HYDROXYZINE AND TERRAMYCIN AS FEED ADDITIVES FOR STEERS IMPLANTED OR FED STILBESTROL. P. T. Marion, J. H. Jones and E. E. Hughes, *Texas Agricultural Experiment Station, Spur.*

The tranquilizer hydroxyzine and Terramycin were used as feed additives for yearling steers which had been implanted with 36 mg. or fed 10 mg. of stilbestrol in a 152-day feeding trial. Forty-two steers averaging 755 lb. were divided into one lot of 10 head for the untreated control and four test lots, each of eight head, treated as follows: none; 36-mg. stilbestrol implant; 36-mg. stilbestrol implant plus 2.5 mg. hydroxyzine; 36-mg. stilbestrol implant plus 2.5 mg. hydroxyzine and 80 mg. Terramycin; and 10 mg. oral stilbestrol plus 2.5 mg. hydroxyzine and 80 mg. Terramycin. Daily gains for the five lots of steers averaged 2.24 lb., 2.66 lb., 2.61 lb., 2.82 lb., and 2.80 lb., respectively. Feed required per pound of gain was 13.5% less for the implanted steers without the additives than for the untreated control group. The addition of hydroxyzine alone to the ration did not improve the feed efficiency of implanted steers, but the combination of Terramycin with the tranquilizer increased feed efficiency 6.6% over implanting alone, and 21% over the untreated control steers. Similar increases in gain and feed efficiency resulted when stilbestrol was fed with these two additives, but the steers which were implanted and fed the additives made a net return of $7 per head more than those fed stilbestrol with Terramycin and hydroxyzine.

26. THE VALUE OF TAPAZOLE IN RATIONS WITH ORAL STILBESTROL FOR YEARLING STEERS. P. T. Marion, J. H. Jones and E. E. Hughes, *Texas Agricultural Experiment Station, Spur.*

Two levels of Tapazole were fed in rations containing 10 mg. of stilbestrol during a 152-day feeding trial. Four lots of 10 yearling steers weighing 755 lb. were fed the same ration with the following additives: none; 10 mg. stilbestrol; 300 mg. Tapazole plus 10 mg. stilbestrol; and 600 mg. Tapazole plus 10 mg. stilbestrol. Tapazole was fed only the last 60 days and stilbestrol was fed the entire feeding period. Average daily gains for the four lots of steers were: 2.24 lb., 2.62 lb., 2.49 lb. and 2.65 lb., respectively. Carcass grades were higher for the steers fed Tapazole with 4 Choice and 6 Good on the 600-mg. level, and 3 Choice and 6 Good on the 300-mg. level, compared with only 2 Choice and 8 Good from those fed stilbestrol alone. There were also 4 Choice and 6 Good carcasses from the untreated group. The steers fed stilbestrol alone gained 93 lb. during the last 60 days of the feeding period while those on the 300-mg. level of Tapazole gained 96 lb. and those on the 600-mg. level gained 125 lb.

27. EFFECT OF HORMONE IMPLANTS ON SUCKLING LAMBS. J. W. Oxley, C. J. Kercher, O. L. Nicholls, M. W. Wall, L. C. Patterson, P. B. Coxe and R. G. Hiser, *University of Wyoming, Laramie.*

In 1958 two trials involving 299 animals were conducted to determine the response of suckling wether and ewe lambs summered in the National Forest to the administration of 3- and 6-mg. stilbestrol (DES) implants. In two trials in 1959, 197 suckling wether lambs summered in the National Forest were randomly allotted to the following treatments: controls, 3 mg. DES, 6 mg. DES, and Synovex-L. An additional trial was conducted with 44 suckling ewe and wether lambs to determine the effect of 6 mg. DES on weight gains with creep feeding under drylot conditions. All lambs were weighed, eartagged, and implanted at 9 to 24 days of age and at weights of 19 to 35 lb. Final weights, taken from 74 to 122 days after implanting, varied from 54 to 93 lb. In the 1958 trials, 3-mg. DES implants failed to increase daily gains appreciably; in one trial there was a significant decrease. The 6-mg. level increased gains about 0.05

lb. daily in one trial but did not materially affect gains in the second trial. Both sexes responded similarly to the two levels of hormones. In 1959 trials the 3-mg. DES improved gains from 4 to 7%, the latter increase being significant. Six mg. DES significantly improved gains about 9% in two of the trials and about 15% in the third one. Wether lambs implanted with Synovex-L gained 10% more than the controls in both trials. The increase was highly significant in one trial but not in the other. Adverse side effects were not observed.

28. RESPONSE OF BEEF STEERS TO MULTIPLE STILBESTROL IMPLANTS, PRE-WEANING, WEANING, GRAZING AND FEEDLOT. C. B. Roubicek, E. S. Erwin, G. E. Nelms and Bruce Taylor, *University of Arizona, Tucson.*

Hereford steers were subjected to stilbestrol implants at various times starting at approximately 2 months of age and continuing through the feedlot. Treatments included: no stilbestrol (control), stilbestrol implanted at pre-weaning, weaning, yearling and in feedlot, plus combinations of these in which some steers received four implants. In addition, the feedlot phase included feedlot response to oral stilbestrol of previously range-implanted steers. All range implants, except the weaning implant alone, significantly increased weight gains. There were no apparent adverse effects from range implants. Steers that received a 24-mg. feedlot implant gained significantly more than controls or those fed 10 mg. of stilbestrol per head daily. The various range implants had no significant effect on feedlot gain regardless of feedlot treatment. Carcass grade was not influenced by treatment; however, steers implanted in the feedlot produced carcasses with a significantly larger rib-eye area than controls or those fed stilbestrol.

29. EFFECT OF DIALLYLSTILBESTROL AND DIALLYLHEXESTEROL IMPLANTS, AND A COMBINATION OF THE TWO, ON THE WEIGHT GAINS OF WEANED BEEF STEER CALVES. O. O. Thomas and John Doty, *Montana State College, Bozeman.*

One hundred and sixty-six weaned Hereford steer calves averaging about 470 lb. were randomly divided into 13 groups of 12 head each. The calves were individually weighed and placed on experiment January 9, 1960. At this time, they were implanted with various levels of DAS (diallylstilbestrol), DAH (diallylhexesterol), or DAS-DAH (a combination of the two). The calves were fed together in a commercial-type feedlot an average daily ration of about 13 lb. of chopped alfalfa hay and 1 lb. of ground barley. The calves were "weighed off" the experiment on March 23, 1960. Implant levels and average daily gains (lb.) were as follows: Control, 1.16; 12 mg. DAS, 1.46; 24 mg. DAS, 1.41; 48 mg. DAS, 1.26; 96 mg. DAS, 1.24; 12 mg. DAH, 1.36; 24 mg. DAH, 1.36; 48 mg. DAH, 1.39; 96 mg. DAH, 1.07; 12 mg. DAS-DAH, 1.18; 24 mg. DAS-DAH, 1.12; 48 mg. DAS-DAH, 1.43; and 96 mg. DAS-DAH, 1.12. Steers implanted with 96 mg. of DAH, or 12, 24, or 96 mg. of DAS-DAH gained less than the controls. No side effects were noted.

30. VALUE OF DIALLYLSTILBESTROL AND ZYMO-PABST ENZYME PREPARATION FOR FATTENING YEARLING STEERS. Conrad J. Kercher, *University of Wyoming, Laramie.*

Forty-eight yearling Hereford steers were randomly divided into six lots of eight steers each. Two lots of steers were randomly assigned the following treatments: (1) controls; (2) 25 mg. of diallylstilbestrol per day; and (3) 4 gm. of Zymo-Pabst enzyme per day. All steers were fed a basal ration of approximately 3.5 lb. alfalfa hay, 13.5 lb. corn silage, and 14–15 lb. grain per head daily during the 154-day feeding

period. The grain ration was comprised of 50% steam-rolled barley, 40% dried beet pulp, and 10% steam-rolled oats. One-half pound of ground corn per head daily was fed as a carrier for the additives. The average daily gain, in-transit shrink (425 miles), and live grades were (1) 2.42 lb., 3.77%, 2.32, (2) 2.35 lb., 4.16%, 2.38, and (3) 2.34 lb., 3.99%, 2.13. The average carcass grades, length of loin, and length of body were (1) 7.63, 62.9 cm., 119.2 cm., (2) 7.13, 62.3 cm., 118.8 cm., (3) 7.50, 62.3 cm., 118.8 cm. (A higher number score indicates a higher live and carcass grade.) Differences were not significant. The dressing percentages based on final feedlot weights and warm carcass weights were (1) 59.85, (2) 60.65, and (3) 60.97. The steers fed the additives yielded significantly more carcass than the controls.

31. INFLUENCE OF YEAST IN A HIGH ROUGHAGE WINTERING RATION FOR HEREFORD CALVES AS MEASURED BY DIGESTIBILITY AND PERFORMANCE. Joe D. Wallace and Robert J. Raleigh, *Squaw Butte-Harney Experiment Station, Burns, Oregon.*

The influence of yeast was studied on the *in vitro* digestion of cellulose and on *in vivo* digestion of cellulose, dry matter, and crude protein by weaned Hereford steers. Body gain and feed intake data were obtained over a period of 112 days. Yeast was added to native meadow hay samples and to purified cellulose in the artificial rumen to measure its effect on cellulose digestion. The percent cellulose digestion was doubled when yeast was added to the purified cellulose; whereas, yeast added to the meadow hay samples increased cellulose digestion by 10% plus. Nine uniform Hereford calves were stratified by weight into three replications. One steer of each replication was randomly allotted to one of three treatments. All steers were allowed to eat meadow hay, *ad libitum*. Treatments 2 and 3 were an additional 2.0 lb. of barley, and 1.85 lb. of barley plus 0.15 lb. of yeast, respectively. Both treatments increased gain, but yeast added to the barley ration did not significantly increase gain over that made on barley. Average daily gains were 0.36, 0.73, and 0.81 lb. for hay alone; hay and barley; and hay, barley, and yeast groups, respectively. Hay consumption was not significantly affected by yeast. At the close of the feeding period digestion trials were conducted with all the steers. Cellulose, dry matter, or crude protein digestibility was not significantly affected by the yeast treatment.

32. LYSINE AND METHIONINE SUPPLEMENTATION IN THE RABBIT RATION. R. B. Casady and A. E. Suitor, *U. S. Rabbit Experiment Station, Fontana, California,* and R. A. Damon, *Biometrical Services, USDA, Beltsville, Maryland.*

A total of 136 does and 1757 young rabbits were used in two experiments. In the first experiment, the following supplements were added to the basic ration in use at the rabbit experiment station: methionine 0.1%, methionine 0.2%, lysine 0.2%, lysine 0.2% and methionine 0.1%, lysine 0.2% and methionine 0.2%, lysine 0.4%, lysine 0.4% and methionine 0.1%, lysine 0.4% and methionine 0.2%. The second experiment utilized methionine only, at supplementary levels of 0.1%, 0.2% and 0.4%. In both experiments the basic stock ration was used as a control. Both experiments involved the feeding of mature females and their young from mating of the does until the young were weaned at 56 days of age. Deaths due to enteritis in young rabbits were significantly ($P<0.01$) lower in the group receiving methionine in the first experiment, but higher in the second experiment. No effect of lysine was noted. Weaning weights were increased ($P<0.01$) by supplementing with lysine or methionine, or both, in the first experiment, and by the addition of 0.2% ($P<0.05$) methionine in the second experiment. Curvilinear effects were apparent in both experiments. No effects on feed efficiency were obtained.

33. COMPARATIVE VALUE OF SILAGE AND HAY DURING WINTERING AND FATTENING OF WEANER CALVES. David C. England and Norton O. Taylor, *Oregon State College, Corvallis.*

In experiment 1, 18 weaner steer calves per lot weighing about 470 lb. were fed 2.5 lb. of a grain mixture (11% protein) daily and were allowed free access to either peavine silage or alfalfa hay. Average daily consumption of silage and hay was 27 lb. and 11 lb., respectively, during a 92-day wintering period; average daily gains for the corresponding lots were 1.05 and 1.66 lb., respectively. The experiment continued for 257 days. From the 182nd to the 257th day the grain and roughage intakes were 11.5 lb. and 28 lb., respectively, for the silage-fed lot and 12.0 lb. each for the alfalfa hay-fed lot; average daily gains for these lots were 2.68 and 1.96 lb., respectively. In experiment 2, duplicate lots of 18 head each were fed as above and two additional lots were fed peavine hay as roughage. During a 64-day wintering period, daily roughage intakes averaged 30, 12, and 11 lb. for peavine silage, alfalfa hay and peavine hay, respectively; average daily gains were 1.16, 1.87 and 1.63 lb., respectively. During the last 103 days of a 252-day feeding period, average daily grain and roughage intakes were 11.8 and 28 lb. for peavine silage-fed animals, 12.6 and 11 lb. for alfalfa hay-fed animals, and 12.6 and 11 lb. for peavine hay-fed animals; average daily gains were 2.70, 2.47 and 2.56 lb., respectively. In both experiments there was a marked shift in the relative value of the forages with progression to higher grain levels, warmer temperatures and increased body size.

34. EFFECT OF CONSTANT VERSUS INCREASING RATIOS OF GRAIN TO BODY WEIGHT ON GROWTH RATE OF WEANER STEERS. David C. England and Norton O. Taylor, *Oregon State College, Corvallis.*

In three experiments a total of 162 weaner steer calves were fed grain at a constant ratio of grain to body weight in comparison to feeding grain at an increasing ratio (grain: body weight) as the feeding period progressed. Initial weight of steers averaged about 470 lb. The feeding period was about 250 days. The daily grain ration was fed as a percentage of the average liveweight per animal in each group. For groups receiving increasing grain ratios (percentages), the grain at each ratio was fed for approximately the same length of time. Peavine silage was fed free choice at each of the following grain percentages: (1) 1.5%, constant; (2) 1.0%, constant; (3) a sliding scale of 0.5% initially, 1.0% during the middle of the feeding period, and 1.5% at the end of the period; and (4) as in (3) except that four percentages were used, 2% being used at the end. In each experiment the sliding scale method has resulted in faster growth on a comparable total feed intake.

35. EFFECT OF VARIOUS ROUGHAGE-CONCENTRATE RATIOS IN PELLETED AND NON-PELLETED RATIONS ON WEIGHT GAINS OF LAMBS. O. O. Thomas, Leonard Joppa, Glenn Hartman and J. L. Van Horn, *Montana State College, Bozeman.*

Two lamb fattening trials were conducted. In trial I, 207 lambs were divided into nine lots and self-fed from September 25 to December 18, 1958. Alfalfa hay was used as the roughage; the concentrate was composed of two-thirds barley and one-third dried molasses beet pulp. Lot 1 lambs, fed hay *ad libitum*, gained 0.43 lb. Lot 2, 3, 4, and 5 lambs were fed chopped alfalfa mixed with the grain; roughage levels and gains were as follows: Lot 2, 70%, 0.34 lb.; Lot 3, 50%, 0.43 lb.; Lot 4, 30%, 0.39 lb.; Lot 5, 70–50–30%, 0.42 lb. Lots 6, 7, 8, and 9 were fed their rations in a completely pelleted form; roughage levels and gains were as follows: Lot 6, 70%.

0.51 lb.; Lot 7, 50%, 0.47 lb.; Lot 8, 30%, 0.51 lb.; Lot 9, 70–50–30%, 0.46 lb. In trial II, 162 lambs were fed from September 30 to December 9, 1959. The design of the trial was the same as the previous year except that the roughage levels were changed to 65, 50, or 35%. Roughage levels and average daily gains were as follows: Lot 1, hay *ad libitum*, 0.40 lb.; Lot 2, 65%, 0.38 lb.; Lot 3, 50%, 0.44 lb.; Lot 4, 35%, 0.43 lb.; Lot 5, 65–50–35%, 0.44 lb.; Lot 6, 65%, 0.47 lb.; Lot 7, 50%, 0.45 lb.; Lot 8, 35%, 0.48 lb.; Lot 9, 65–50–35%, 0.51 lb. Greater gains were made in both trials with rations fed in pelleted form—6, 7, 8, and 9. In both trials, lambs fed Ration 8, 30% and 35% hay in a completely pelleted ration, made the most efficient gains.

36. RESPONSE OF THREE BREEDS OF SHEEP TO DIFFERENT LEVELS OF NUTRITIVE INTAKE. J. L. Van Horn, D. W. Blackmore, A. S. Hoversland and J. Drummond, *Montana Agricultural Experiment Station, Bozeman.*

Rambouillet, Targhee and Columbia ewes were assigned to two different treatments during gestation for three different winters. On one treatment the ewes were wintered on the range and did not receive any supplemental feed. The ewes on the other treatment were wintered in dry lot and allowed to eat native meadow hay *ad libitum*. The ewes were all in one band during the rest of the year. The ages of the ewes ranged from yearlings (20 months old) to six-year-olds at the beginning of the trials. The percentage of yearling ewes by breeds was as follows: Rambouillets 26, Targhees 21, and Columbias 27. Initial body weights averaged 135, 138 and 132 lb. for the Rambouillets, Targhees and Columbias respectively. The ewes that grazed on the range without supplement lost an average of 1.3 lb. each year for the three-year experiment, and the ewes fed in dry lot gained an average of 15.7 lb. The average yearly gain for each breed (combined treatments) was: Rambouillet 8.3, Targhee 6.1, and Columbia 6.0 lb. during the three-year period. The difference in weight changes between treatments and between breeds was significant ($P<.01$ and .05, respectively). The difference in fleece weights between treatments and years was significant ($P<.05$) and between breeds was significant ($P<.01$). Treatments, years and breed did not significantly affect the pounds of lamb produced per ewe bred.

37. EFFECT OF BARLEY HULLS AND PURIFIED CELLULOSE IN SWINE RATIONS ON CARCASS COMPOSITION. L. M. Larsen, Patricia Bertun, D. C. England and J. E. Oldfield, *Oregon State College, Corvallis.*

It is generally accepted that increasing the fiber content of swine rations lowers fat deposition in the carcass. Since qualitative differences in the fiber may affect carcass fatness, a trial was initiated to explore this point. Forty-eight individually fed weaner pigs were involved in a 2x3 factorial experiment in which the two grain components, barley and corn, were each fed in three variations, *viz.*, pearled barley, regular barley and barley plus wood cellulose; versus, corn, corn plus barley hulls and corn plus wood cellulose. Animals were slaughtered at 200 lb. live weight and dressing percentage, carcass length, backfat thickness and percent fat in a probe sample taken through the loin at the 13th rib were determined. Barley hulls decreased backfat thickness on both corn and barley rations, while wood cellulose lowered backfat thickness on corn rations but not on pearled barley. There were no significant differences in dressing percentages or carcass lengths. Estimates of separable carcass fat made by the loin probe technique also showed decreased fat deposition on the barley hulls but not on the cellulose rations. Crude fiber level *per se* was not significantly correlated with either average backfat thickness ($r=.23$) or with estimated carcass fat content ($r=-.20$).

38. BIOLOGICAL RESPONSES OF MICE FED BULKY RATIONS. C. W. Fox, R. W. Mason, R. L. Manning and J. E. Oldfield, *Oregon State College, Corvallis.*

Red clover, Sudan grass and orchard grass were incorporated into stock diets for laboratory mice with the following modifications: (1) Stock diet, *ad libitum;* (2) Stock diet at sub-maintenance level; (3) Stock diet + cellulose to equal 15% of dry matter; (4) Stock diet + cellulose + water to yield 65% moisture content; (5–7) Stock diet + red clover, Sudan grass or orchard grass as 40% of dry matter; (8–9) Stock diet + freeze dried red clover or orchard grass as 40% of dry matter; (10–11) Stock diet + acetone extracts of red clover and Sudan grass equivalent to 40% of dry matter. All diets except 1 and 2 were frozen until fed. Diet treatments were based on average composition of the forages, 65% moisture, and 15% cellulose in the dry matter. Ten or twenty normal, mature female mice were fed for 10 days on each diet. Limited food intake decreased all organ weights except brain and stomach. Addition of cellulose increased clean stomach weight, while cellulose + water addition increased stomach and intestine weights and decreased vaginal and uterine weights. Inclusion of bulky, wet or frozen items in the diets led to increased food consumption and, in general, decreased organ weights. It is recommended that control rations be comparable to the test ration in cellulose and moisture content and that feeding of the test ration be preceded by several days of feeding the appropriate control ration.

39. EFFECT OF PLANE OF NUTRITION ON GROWTH RATE AND HEMATOLOGY OF WEANLING RANGE HEIFERS. W. W. Repp, W. H. Gossett, L. A. Holland and J. H. Knox, *New Mexico State University, University Park.*

Thirty-two weanling Hereford range heifers were pasture-fed for various periods a supplement furnishing 40% of the TDN, 80% of the digestible protein and 100% of the carotene requirement for a gain of 0.75 to 1.0 lb. per day. Period I was the first four months immediately following weaning; Period II was the second, and Period III was a five-month period beginning when the heifers were 19 months old. This made a design allowing eight feeding treatments as follows: XXX, XXO, XOO, XOX, OXX, OXO, OOX and OOO where X indicates supplement feeding and O indicates no supplement for all possible combinations of the three periods. Weight gains over the 17 months of the study were 415, 307, 296, 416, 379, 281, 398 and 284 lb. for the eight treatments as listed above, respectively. The influence of these treatments on rate of gain, heart girth, wither height, hemoglobin, hematocrit, plasma proteins, carotene and inorganic phosphorus was studied. Hemoglobin, hematocrit and plasma non-protein nitrogen varied inversely with rate of gain. In an additional replication of this experiment blood volume of heifers unsupplemented during the 4 months following weaning was reduced whereas supplemented heifers maintained blood volume.

40. PERFORMANCE, SERUM PROTEIN FRACTIONS AND SERUM LIPOPROTEIN FRACTIONS OF BEEF CATTLE AS INFLUENCED BY ALFALFA STAGE OF MATURITY AND FAT ADDITIONS TO A GROWING-FATTENING RATION. Farris Hubbert, Jr., T. R. Varnell, Bruce Taylor, C. B. Roubicek and John Kuhn, *University of Arizona, Tucson.*

Sixty yearling steers were allotted to an 111-day, 2x2 factorial study of the influence of pre-bloom or full-bloom alfalfa hay and hydrogenated vegetable oil. All animals were fed 0.9 lb. ground barley per 100 lb. body weight; 0.75 lb. of hydrogenated vegetable oil, when fed, replaced an equal amount of barley. Alfalfa hay was full-fed. Crude protein content of the pre-bloom and full-bloom hays was 18.7 and 13.5% and the crude fiber content 22.8 and 29.8%, respectively. The average daily

gains and feed per pound of gain were: pre-bloom 1.93, 9.74; pre-bloom plus oil 2.25, 8.62; full-bloom 1.82, 10.62; and full-bloom plus oil 2.11, 9.33. The difference in average daily gain due to the addition of hydrogenated vegetable oil was significant ($P<0.05$). Electrophoretic separations were made on blood serum samples taken at the end of the trial. Dietary treatments did not result in a significant change in serum protein fractions. The serum lipoproteins for the animals receiving no vegetable oil were separated into 49.4, 22.6, 16.4 and 11.6% for fractions 1, 2, 3, and 4, respectively; those for the oil-fed animals separated into 58.0, 20.4, 13.6 and 8.0% for the first through fourth fractions, respectively. The differences due to the oil addition were significant ($P<0.05$) for fractions 1 and 4. This indicates that a shift in lipoprotein fractions can result from a difference in the content of fat in a ruminant's ration.

41. AN ARTIFICIAL RUMEN TECHNIQUE VERSUS CONVENTIONAL DIGESTION TRIALS FOR DETERMINING DIGESTIBILITY OF BLUE GRAMA, SUDAN AND ALFALFA HAYS. Billie G. Taylor, W. W. Repp and W. E. Watkins, *New Mexico State University, University Park.*

A simplified *in vitro* method which makes use of raw sheep rumen liquor was compared to the conventional method of determining digestibility of cellulose in blue grama, sudan and alfalfa hays. Five conventional digestion trials (three with blue grama and one each with sudan and alfalfa) were conducted with six sheep per trial. Two rumen-fistulated sheep fed alfalfa hay were used as the source of the rumen liquor for 12, 48-hour *in vitro* fermentations. Each fermentation tube contained 20 ml. raw rumen liquor, 7.5 ml. artificial saliva, 0.3 gm. hay and enough concentrated Na_2CO_3 to bring the initial pH to neutrality. With 95% confidence cellulose digestibility in percent as measured by the *in vitro* and *in vivo* methods, respectively, was 60.68 ± 1.22 and 59.88 ± 4.02 for alfalfa; 60.70 ± 1.25 and 66.82 ± 1.90 for blue grama; and 57.32 ± 0.97 and 63.84 ± 5.83 for sudan. Analysis of variance indicated significant differences in cellulose digestion among hays by both methods and significant differences between sheep by the *in vitro* method.

42. SPACE ALLOTMENT AND PERFORMANCE OF GROWING-FINISHING SWINE RAISED IN CONFINEMENT. Hubert Heitman, Jr., C. F. Kelly, LeRoy Hahn and T. E. Bond, *University of California and U. S. Department of Agriculture, Davis.*

Two replicates of a 3 x 3 factorially designed experiment involving 126 growing-finishing hogs have been completed using space allotments of 5, 10 and 20 sq. ft. per pig and pig numbers of 3, 6 and 12 per pen. Initial weights and feeding periods were 70 and 80 lb. and 70 and 68 days for the two replicates, respectively. Hogs were self-fed a standard ration and were confined in a large, concrete-floored barn. Pens were cleaned daily by washing. Hogs with 20 sq. ft. each gained weight more rapidly than those confined each to 10 or 5 sq. ft. ($P<.01$). Number of pigs per pen had no effect on weight increase. Space allotment per pig had no significant effect on average daily feed consumption, but pigs consumed more feed per day when there were 3 per pen compared to either 6 ($P<.05$) or 12 per pen ($P<.01$). Pigs with 5 sq. ft. each required more feed per unit of gain than those with 20 sq. ft. ($P<.01$), and pigs in groups of 3 used more feed per unit of gain than those with either 6 ($P<.05$) or 12 per pen ($P<.01$). There were no differences in fatness at the conclusion of the replicates as determined by live backfat probe.

NEWS AND NOTES

Meeting of the American Society of Animal Production. The 52nd annual meeting will be held at the Hotel Sherman, Chicago, Friday and Saturday, November 25 and 26, 1960. Registration is at 8:00 a.m. Friday. Sectional meetings that day will be held from 9:30–11:00 a.m. and a general session at 11:00 a.m.–12:00. Sectional meetings will continue Friday afternoon 1:00–4:00 p.m. and on Saturday, 9:00 a.m.–12:00; 1:00–4:00 p.m. and, 7:30–9:30 p.m. The annual dinner and presentation of awards will be held on Friday, 6:00 p.m. and will be followed by the annual business meeting.

The Division of Biological and Medical Sciences of the National Science Foundation announces that the next closing date for receipt of basic research proposals in the Life Sciences is September 15, 1960. Proposals received prior to that date will be reviewed at the fall meetings of the Foundation's advisory panels and disposition will be made approximately four months following the closing date. Proposals received after the September 15, 1960, closing date will be reviewed following the spring closing date of January 15, 1961. Inquiries should be addressed to the National Science Foundation, Washington 25, D. C.

Training Program for Endocrinology. The University of Wisconsin Graduate School at Madison announces a postdoctoral training program in endocrinology beginning July 1, 1960. Its purpose is to increase the qualified personnel for teaching and carrying on research in endocrinology. Breadth of training will be emphasized. It will consist of an integrated program of laboratory research, seminars, colloquia, work shops, and teaching under the coordinated auspices of faculty members from the colleges of Letters and Science, Medicine and Agriculture. Candidates for postdoctoral fellowships (M.D. or Ph.D.) will be selected on the basis of professional promise and career interest. Appointments will carry a yearly stipend of $6500. Applicants may apply anytime after July 1, 1960. Send inquiries and requests for applications to: Dr. W. H. McShan, Birge Hall, University of Wisconsin, Madison 6, Wisconsin.

Techniques and Procedures in Animal Production Research. A Monograph in the process of publication by the American Society of Animal Production. The Monograph is composed of the following sections: Design and Analysis of Animal Husbandry Experiments by C. R. Henderson; Techniques for Research in Quantitative Animal Genetics by Gordon E. Dickerson; Research Techniques in Physiology of Reproduction in the Female by L. E. Casida; Design for Comparative Feeding Trials by E. W. Crampton; Methods Employed in Nutrition Research by Ivan L. Lindahl; Meat Research Techniques Pertinent to Animal Production Research by O. G. Hankins, A. M. Gaddis and W. L. Sulzbacher. One copy will be supplied free to each member of the Society. Other persons, including subscribers, may order copies at $4.00 each to the U. S. and Canada, and $4.25 each to other countries from C. E. Terrill, Animal Husbandry Research Division, Agricultural Research Center, Beltsville, Maryland. Copies should be ready to mail soon.

Grasslands—A Symposium presented at the New York meeting of the American Association for the Advancement of Science. Edited by Howard B. Sprague. 424 pages, $8.00 to AAAS members, $9.00 to others. Publication No. 53 of the AAAS, Washington, D. C. 1959. This volume includes 37 papers by 44 recognized authorities in soils, botany, entomology, meterology, agricultural engineering, plant ecology, soil conservation, range management, animal nutrition, dairying, animal husbandry, and agronomy. These papers are grouped into eight chapters as follows: Sciences in Support of Grassland Research; Forage Production in Temperate Humid Regions; Engineering Aspects of Grassland Agriculture; Forage Utilization and Related Animal

Nutrition Problems; Evaluation of the Nutritive Significance of Forages; Grassland Climatology; Ecology of Grasslands; and Range Management. This volume should prove helpful to the large group of scientists who are desirous of keeping abreast of progress on the broad front of grasslands research, beyond the field of their own specialization.—*W. P. Garrigus*

Beef Cattle Production by Kenneth A. Wagnon, Reuben Albaugh and the late George H. Hart; 537 pages; $8.50; The Macmillan Co., New York, 1960. This new book covers the field of beef cattle production including material on breeding, feeding, management and marketing. Research information is supplemented by the wide experiences of the authors to develop practical management recommendations. Important data are documented and an effort is made to present both sides of controversial subjects. Relationships of biological principles to economic aspects of beef production are stressed. Chapters on pasture and range management, influence of droughts, nutritional value of beef, nutritional deficiencies, diseases and parasites and beef cattle equipment are included. Throughout the book the authors have drawn heavily on California and other western work. Thus, while not limited in its usefulness to western areas, it emphasizes western aspects to perhaps a greater degree than any other general beef cattle book in print.—*E.J.W.*

The Artificial Insemination of Farm Animals (third revised edition), edited by E. J. Perry; authored by E. J. Perry, J. Edwards, T. Mann, R. P. Reece, P. Bhattacharya, C. E. Terrill, V. Berliner, J. R. Smyth, F. P. Jeffrey, J. Aamdal, E. P. Leonard, J. W. Bartlett, H. A. Herman, and L. L. Larson; 430 pages; $6.50; Rutgers University Press, New Brunswick, New Jersey, 1960. This book of 21 chapters represents a revision of information found in earlier editions and added chapters concerning water buffaloes, chemical evaluation of semen, and techniques of semen freezing. The authors have done a good job of bringing research information and practical experience together for the student and the artificial breeding industry. The subject matter is presented in a logical and orderly manner. Chapters dealing with the breeding of cattle, sheep and goats, horses and jackstock, poultry, swine, and dogs have been markedly improved. The chapters dealing with semen quality, semen handling and hormones related to reproduction have been enhanced by revision and new information included. The chapter dealing with diseases and health standards for bulls in artificial insemination is a definite improvement over earlier editions. However, the section on diseases does not yet truly reflect the importance of this subject or present it in such a way as to give the layman an adequate appreciation of the problems involved and precautions that are essential for good herd health.—*S.D.M.*

Fundamentals of Nutrition by E. W. Crampton and L. E. Lloyd; 494 pages; $7.50; W. H. Freeman and Company, San Francisco, California, 1960. This book might be considered in one sense a companion volume to Crampton's Applied Animal Nutrition. Whereas the latter volume tends to relate the value of feedstuffs to the nutritional requirements of farm animals as a basis for feeding practice, the present work surveys a wider area and draws more directly upon those branches of biochemistry, physiology and related sciences that form the framework of nutrition. Chapters are grouped under six sections. The first section contains arbitrarily chosen material that introduces the student to some facts of nutrition. The second deals with the metabolism of carbohydrate, fat and protein in the conventional manner of introductory biochemistry but treats this material without benefit of structural chemical formulas to show relationships. Similarly, two sections, each of about 50 pages, discuss the importance of vitamins and minerals. One section considers experimental nutrition under such headings, among others, as comparative feeding trials, coefficients of apparent digestibility, physiological fuel value and nutritional balances, and a final section covers the nutrient needs of animals.

Principios de Produccion Lechera. Cesar Fernandez-Quintilla. Salvat Editores, S. A., Barcelona and Madrid. 486 pp., 158 illus., 1960. This book is a reproduction in Spanish of Principles of Milk Production by William B. Nevens of the University of Illinois (McGraw-Hill Book Co., New York). The translation has been carried out with exacting detail. The translator has included an additional chapter on species of forage of greatest interest in Spain.—*W.B.N.*

The Effect of Germ Cell Damage on Animal Reproduction. Papers of The Fourth Biennial Symposium on Animal Reproduction which have now been published as a Supplement to Journal of Dairy Science, Volume 43, April, 1960. This 168-page issue consisting of eight papers by internationally recognized authorities is available at a postpaid price of $2.50 per copy. Payment should be sent with order to H. F. Judkins, 32 Ridgeway Circle, White Plains, N. Y.

D. W. Colvard, Dean of Agriculture at North Carolina State College since 1953 was named President of Mississippi State University, effective July 1, 1960. Dr. Colvard received his B.S. degree from Berea College, his M.S. from Missouri University and his Ph.D. from Purdue University. Dr. Colvard was Head of the Animal Industry Department at North Carolina State College from 1948 to 1953.

Fred F. McKenzie, Professor of Animal Husbandry at Oregon State College, has resigned to accept a position with the International Cooperation Administration and will be associated with the University of Kentucky contract in Indonesia during the next two years. He and Mrs. McKenzie left for Indonesia about August 1.

W. V. Lambert has resigned as Dean of the University of Nebraska's College of Agriculture, to accept a staff position with the University of Illinois in India, effective July 1. Dr. Lambert has been Dean of the Nebraska College of Agriculture since 1948. He also held the titles of Director of Resident Instruction, Agricultural Experiment Stations, and the Agricultural Extension Service.

W. A. Craft, formerly Director of the Regional Swine Breeding Laboratory, Ames, Iowa, was given a citation by the Iowa Chapter of Gamma Sigma Delta on March 22, during the honors dinner. Dr. Craft's citation was for distinguished service to the livestock industry, swine breding research, and Federal and State cooperation in research.

Vaughn C. Speer, Virgil W. Hays and J. D. Jones assume responsibility for research and teaching of swine nutrition at Iowa State University following the resignation of Dr. Catron. Dr. Speer will be in charge of the swine nutrition farm and also serve as chairman of the swine nutrition group, which will direct both teaching and research programs. Dr. Hays has had extensive training in the fields of statistics and writing. Both Dr. Speer and Dr. Hays received Ph.D. degrees from Iowa State in 1957. Dr. Jones, who holds a Ph.D. degree from Wisconsin, will be in charge of both basic and applied laboratory work in the swine nutrition area.

Lorin E. Harris, Professor of Animal Husbandry, Utah State University, is studying at the Rowett Research Institute. While in Great Britain, Dr. Harris will present a paper at the 8th International Grasslands Congress and give a series of lectures on the nutrition of sheep.

Harry R. Conrad, Ohio Agircultural Experiment Station, was presented the American Feed Manufacturers award on May 10 at the feed association annual meeting in Chicago.

Dean and Director Robert H. Black, 41, New Mexico, died suddenly of a heart attack on April 12. Since 1956, he was Dean of New Mexico State University's College of Agriculture and Home Economics, Agricultural Experiment Station Director, and

Extension Director. He headed the animal husbandry department at Texas Technological College from 1954 to 1956 and was a member of the animal husbandry staff at West Virginia University from 1940 to 1954. He was a native of Oklahoma, received his B.S. at Oklahoma State University, and his M.S. and Ph.D. degrees from West Virginia University. He was well known in livestock circles as a judge of livestock and meat shows, and as a gifted speaker, as well as an administrator.

J. H. Meyer succeeded H. H. Cole as Chairman of the Department of Animal Husbandry, University of California, Davis, effective July 1. Dr. Cole, who has served as chairman of this department for many years will continue active work in the department.

Verle R. Bohman was appointed Chairman of the Department of Animal Husbandry at the University of Nevada as of May 1. He succeeds Dan Cassard, who will now devote a major part of his time to livestock extension work in Nevada.

Ray E. Ely, formerly Senior Animal Nutritionist in the State Experiment Stations Division, Agricultural Research Service, USDA, Washington, D. C., resigned as of August 1 to become Associate Director of the Nevada Agricultural Experiment Station. Dr. Ely has an M.S. degree from the University of Missouri and a Ph.D. from Michigan State University. He succeeded Associate Director C. E. Fleming.

Oliver Wayman, Head, Animal Science Department, Hawaii Agricultural Experiment Station, will be on a year's sabbatical leave beginning July 1. During this time he will be taking post-doctoral training at the University of Missouri. H. E. Cobb will serve as Acting Head of the Animal Science Department in Dr. Wayman's absence.

W. W. Heinemann, Department of Animal Science, Washington Agricultural Experiment Station (Prosser) attended the Eighth International Grasslands Congress, held at Reading, England, in July, and presented a research paper.

Nelson Gay was appointed Extension Animal Husbandman, Beef Cattle Specialist, February 15, 1960, Lexington, Kentucky. He recently completed his requirements for Ph.D. in Animal Science at the University of Illinois. He replaces Harold White who resigned to take advanced studies toward a Ph.D. degree at the University of Kentucky.

C. Dean Story was made Head, Department of Animal Industry and Chief of the Animal Investigation Section, Colorado State University, on July 1. Dr. Story holds M.S. and Ph.D. degrees from Iowa State University. He succeeds Acting Head, Dr. H. H. Stonaker.

C. S. Hobbs, Head, Animal Husbandry-Veterinary Science Department, University of Tennessee, was recently honored at Stillwater, Oklahoma, as one of Oklahoma's distinguished alumni. His portrait was hung in the "Hall of Fame" of the Animal Husbandry Department.

W. P. Lehrer, Jr., former Associate Professor, University of Idaho, has accepted the position of Director of Nutrition for Albers Milling Company, a division of the Carnation Company, effective July 1, 1960. His new address will be: Carnation Building, 5045 Wilshire Blvd., Los Angeles 36, California.

John W. Stroud has resigned as Assistant Professor of Animal Husbandry at the University of Kentucky and accepted a position as Animal Nutritionist with Pabst Brewing Company, Milwaukee.

Dr. C. Boyd Ramsey, who completed his Ph.D. degree with a major in meats at the University of Kentucky, has accepted a position on the staff of the University of Tennessee, effective June 1.

George W. Thrasher accepted a position in July, 1959 with the Animal Nutrition Research Department at Commercial Solvents Corporation, Terre Haute, Indiana. Dr. Thrasher received his Ph.D. degree in Animal Nutrition from Purdue University.

At the University of Kentucky, Everett C. Simpson and Joe C. Christian are completing requirements for the Ph.D. degree with majors in animal husbandry and emphasis on physiology of reproduction. Dr. Christian will enroll in the new University of Kentucky Medical School this summer. Dr. Simpson has accepted a position on the Zoology staff at Memphis State College.

Earl L. Lasley has resigned as senior Geneticist at the William H. Miner Agricultural Research Institute, Chazy, New York, to accept the position of Geneticist in charge of corn and hog breeding research for the Farmers Hybrid Seed Corn Company and for Farmers Hybrid Hogs of Hampton, Iowa.

Robert R. Shrode has resigned as Geneticist at the William H. Miner Agricultural Research Institute, Chazy, New York, to accept the position of Population Geneticist in poultry breeding research for the DeKalb Agricultural Association with offices in Sycamore, Illinois.

Ralph W. Phillips was among those who received the Superior Service Award at the U. S. Department of Agriculture's annual Awards Ceremony on May 17. Earlier this year Dr. Phillips received a Certificate of Merit and a cash award from the Foreign Agricultural Service for "providing effective United States participation and representation in international organization affairs, thereby contributing substantially to strengthening Agriculture's stature in foreign relations".

At the University of Kentucky, Hobart Jones and John C. Robertson have completed requirements for the Ph.D. degree majoring in animal husbandry with emphasis on swine nutrition. Dr. Jones has returned to his position in Animal Husbandry at Purdue University. Dr. Robertson has accepted a position as Extension Swine Specialist in Western Kentucky, effective July 1.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editoral Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. Consult a recent issue for style and form. The following are guides:

(a) Manuscripts must be typed, double-spaced and the ribbon copy submitted. Submission of two copies (one carbon) will facilitate review.

(b) All pages, including those of tables and legends, must be numbered. The lines of the text, but not of tabular material or "Literature Cited", must be numbered in the left margin, beginning with one at the top of each page.

(c) Tables should be as few and as simple as is feasible for presentation of the essential data. Each table should be on a separate sheet.

(d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnification of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

(e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

(f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: W. D. Gallup, Department of Biochemistry, Oklahoma State University, Stillwater, Oklahoma, or to the publisher: Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, C. E. Terrill, Animal Husbandry Research Division, Agricultural Research Center, Beltsville, Maryland, or to the publishers, Boyd Printing Company, Inc., 49 Sheridan Avenue, Albany 10, N. Y.